Oct. 22, 1957 G. SLAYTER ET AL 2,810,157

METHOD AND APPARATUS FOR PRODUCING FIBERS

Filed March 5, 1952 10 Sheets-Sheet 1

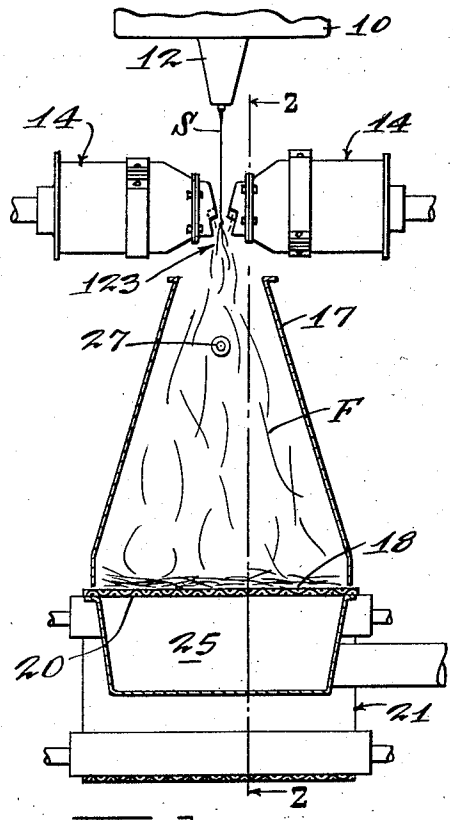


FIG-1-

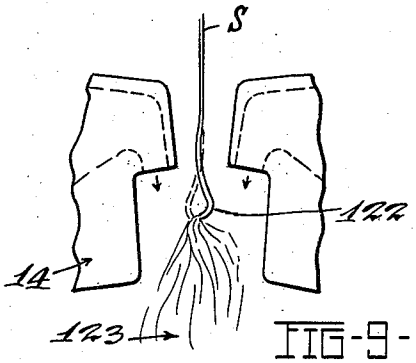


FIG-9-

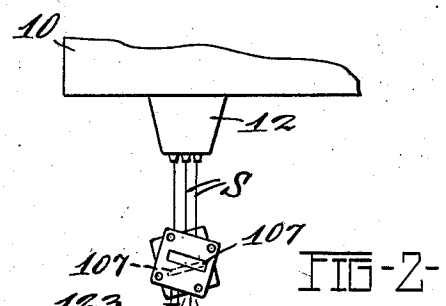
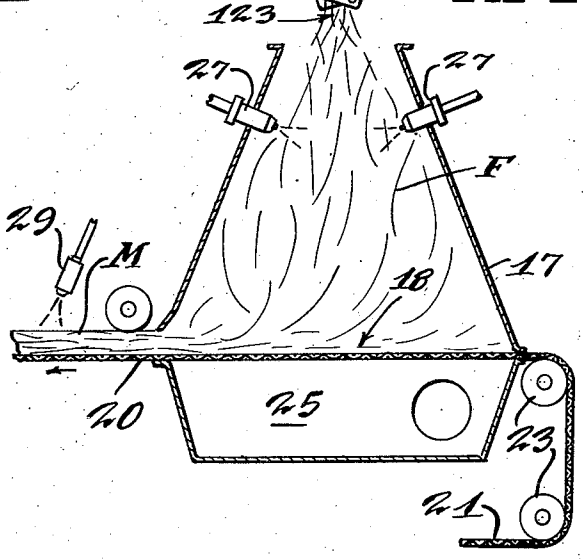


FIG-2-



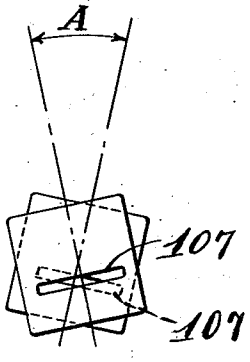


FIG-3-

INVENTORS:
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ED FLETCHER.
BY Starkin & Overman
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Oct. 22, 1957 G. SLAYTER ET AL 2,810,157

METHOD AND APPARATUS FOR PRODUCING FIBERS

Filed March 5, 1952 10 Sheets-Sheet 2

FIG-5

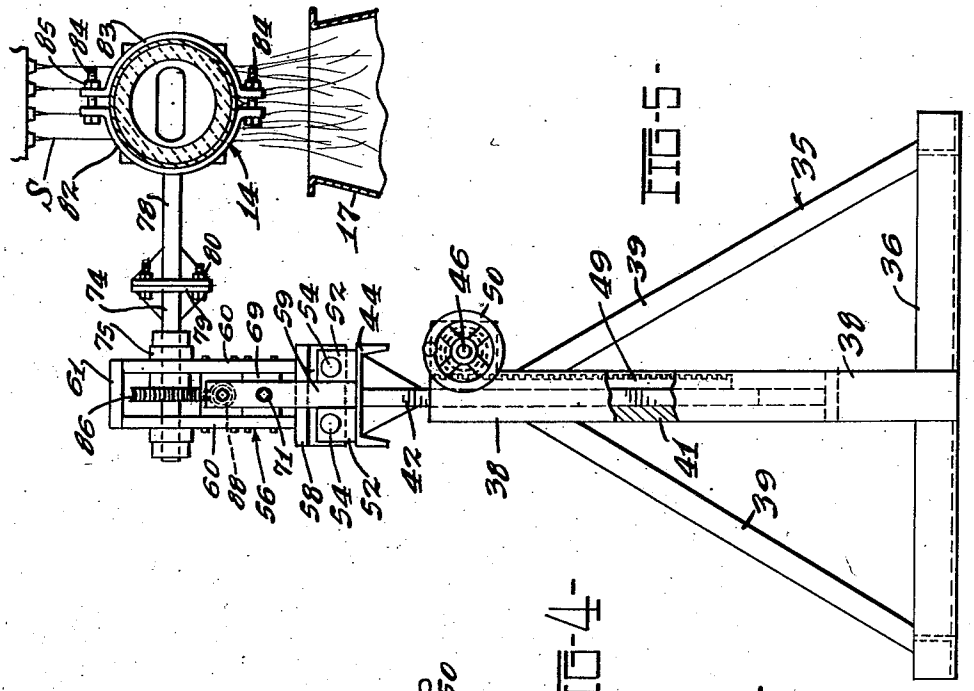
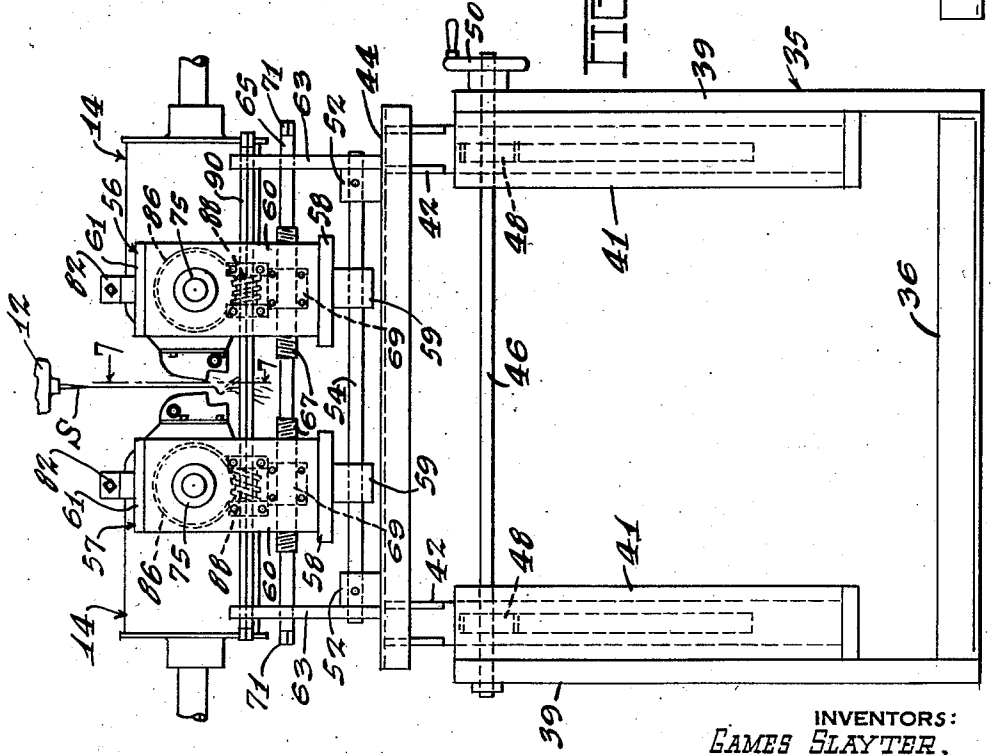


FIG-4



INVENTORS:
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Stachin & Overman
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Oct. 22, 1957 G. SLAYTER ET AL 2,810,157

METHOD AND APPARATUS FOR PRODUCING FIBERS

Filed March 5, 1952 10 Sheets-Sheet 3

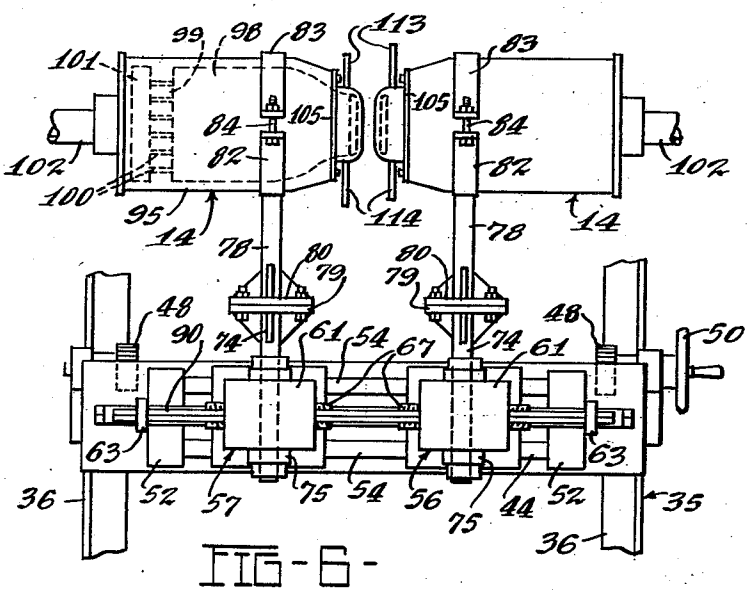


FIG-6-

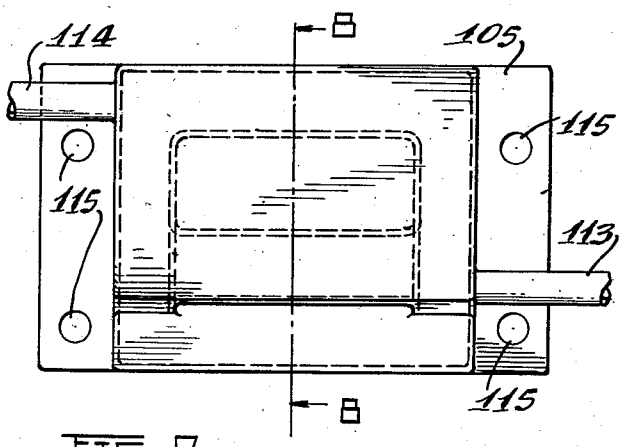


FIG-7-

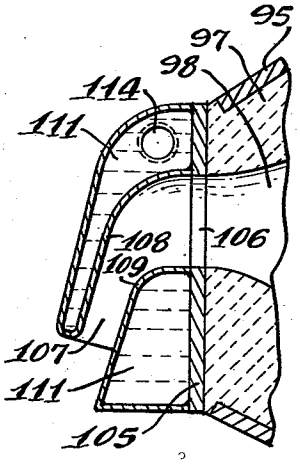


FIG-8-

INVENTORS:
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Oct. 22, 1957 G. SLAYTER ET AL 2,810,157

METHOD AND APPARATUS FOR PRODUCING FIBERS

Filed March 5, 1952 10 Sheets-Sheet 4

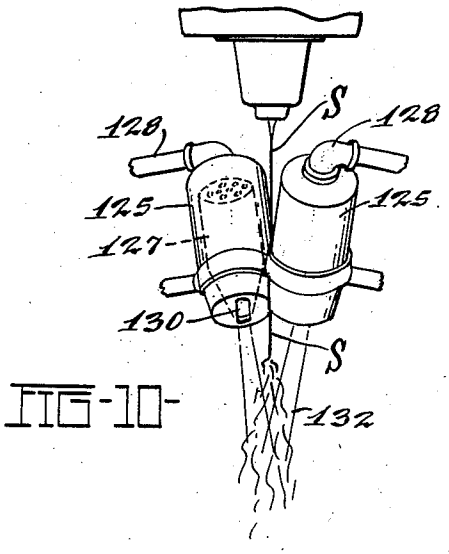


FIG-10-

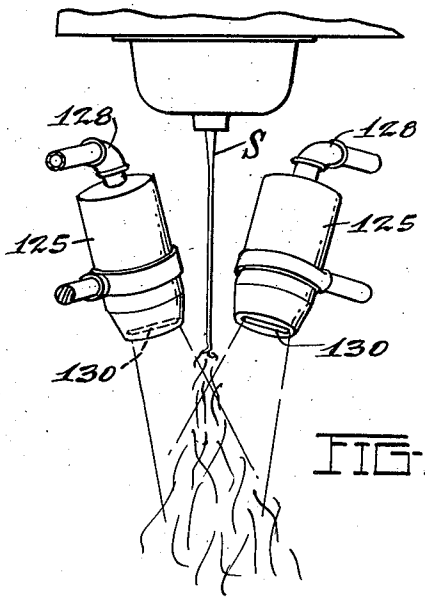


FIG-11-

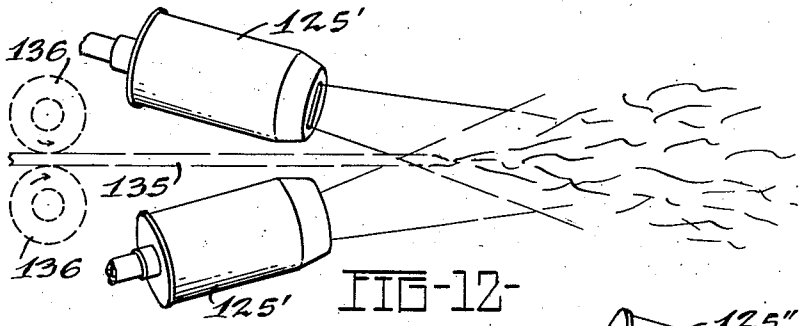


FIG-12-

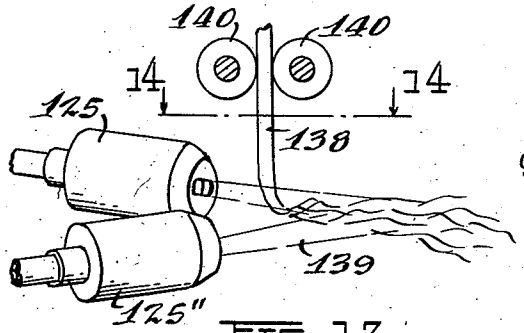


FIG-13-

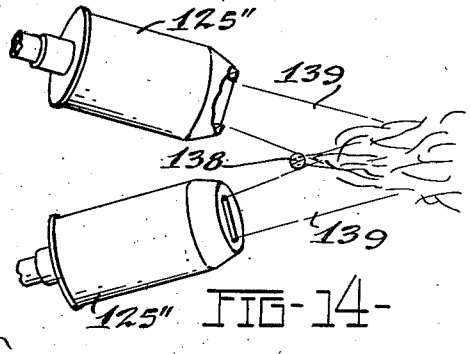


FIG-14-

INVENTORS:
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Stahlin & Osterman
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Oct. 22, 1957 G. SLAYTER ET AL 2,810,157

METHOD AND APPARATUS FOR PRODUCING FIBERS

Filed March 5, 1952 10 Sheets-Sheet 5

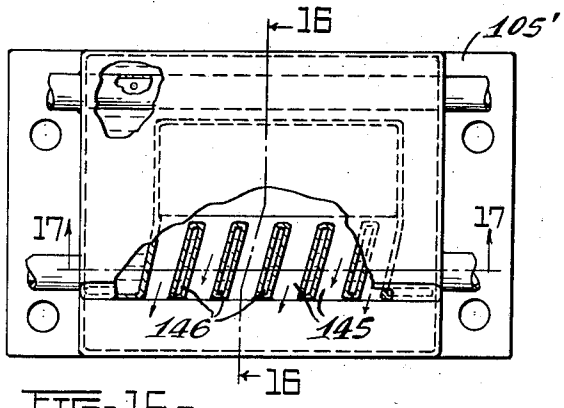


FIG-15-

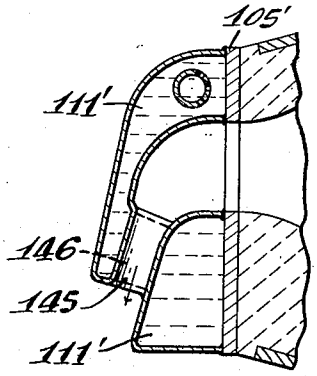


FIG-16-

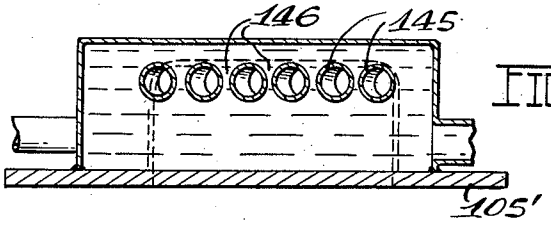


FIG-17-

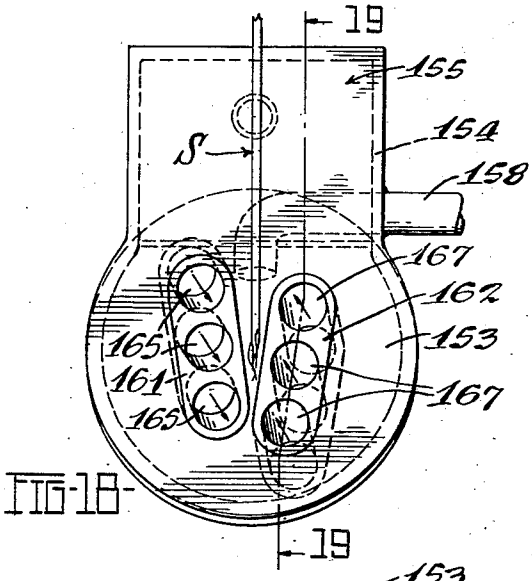


FIG-18-

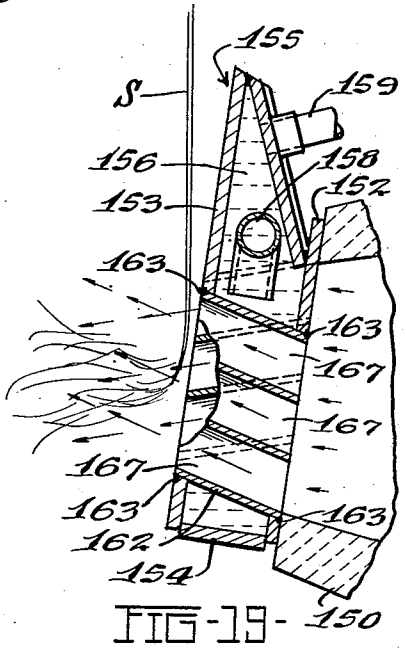


FIG-19-

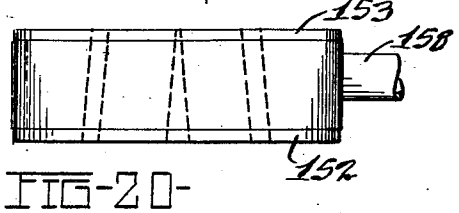


FIG-20-

INVENTORS:
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Oct. 22, 1957 G. SLAYTER ET AL 2,810,157

METHOD AND APPARATUS FOR PRODUCING FIBERS

Filed March 5, 1952 10 Sheets-Sheet 6

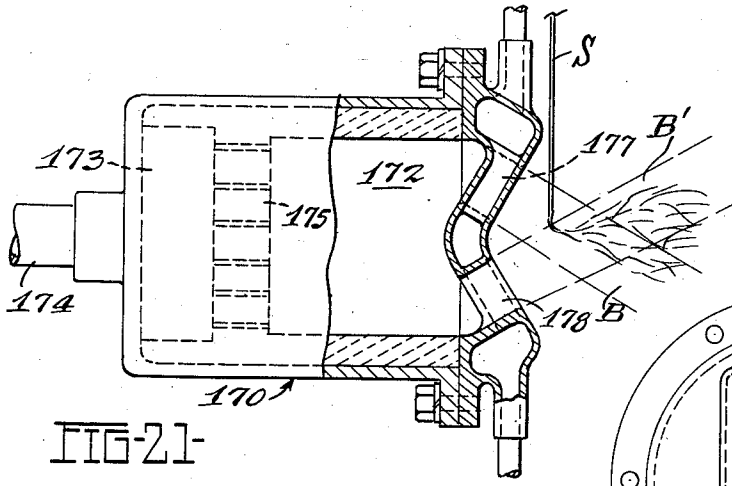


FIG-21-

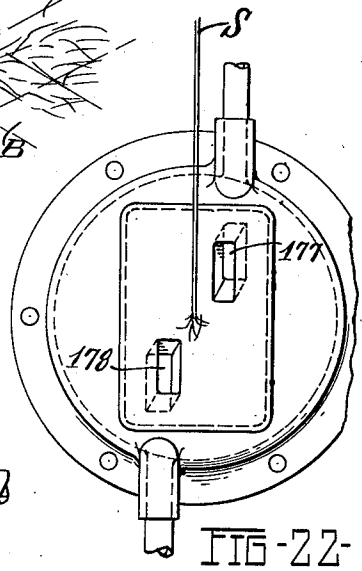


FIG-22-

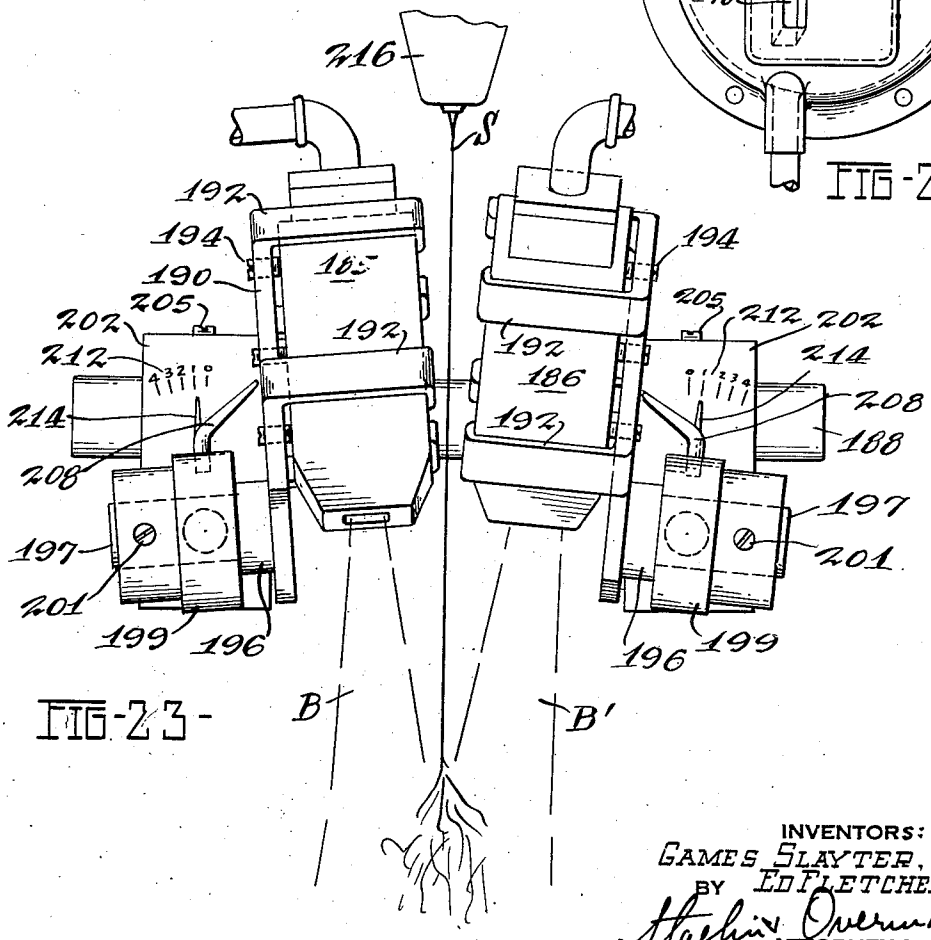


FIG-23-

INVENTORS:
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Oct. 22, 1957 G. SLAYTER ET AL 2,810,157

METHOD AND APPARATUS FOR PRODUCING FIBERS

Filed March 5, 1952 10 Sheets-Sheet 7

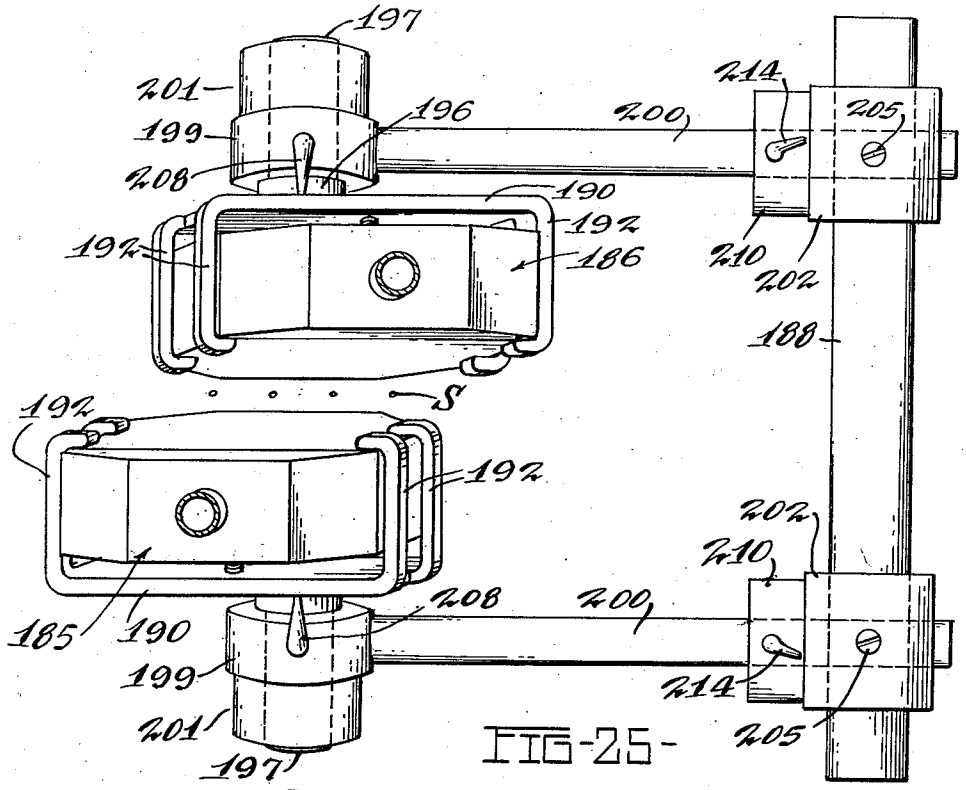


FIG-25-

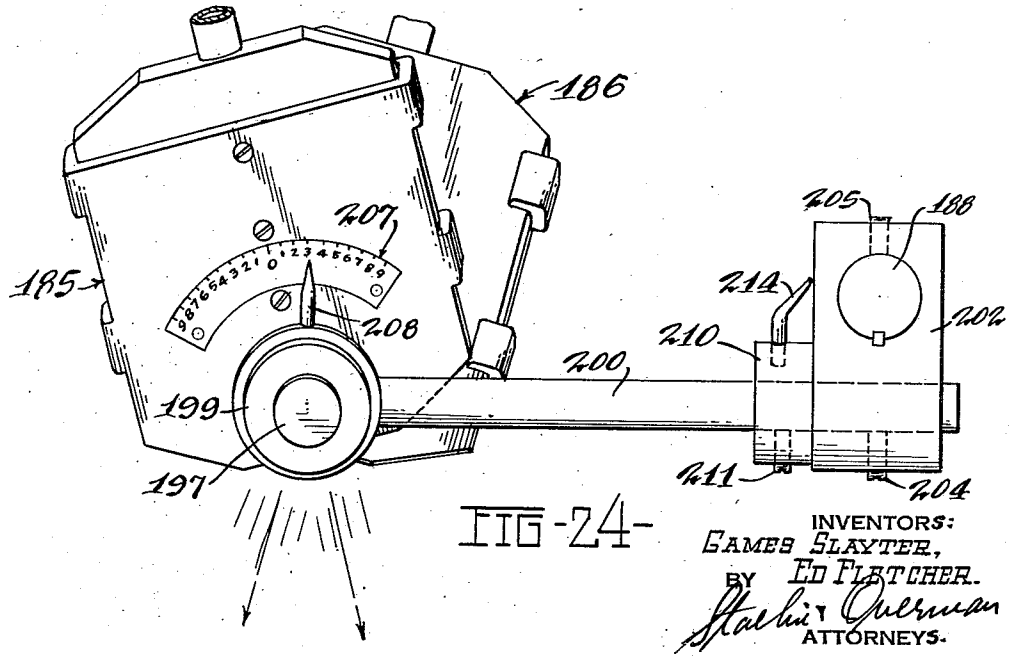


FIG-24-

INVENTORS:
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Stahlman Culman
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Oct. 22, 1957 G. SLAYTER ET AL 2,810,157

METHOD AND APPARATUS FOR PRODUCING FIBERS

Filed March 5, 1952 10 Sheets-Sheet 8

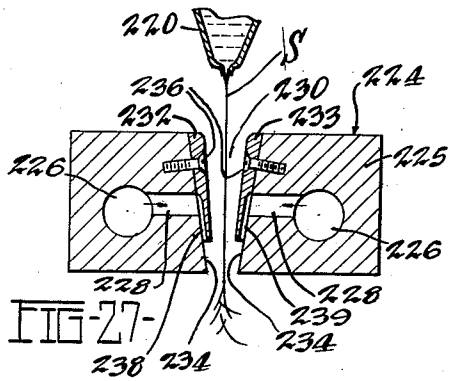


FIG-27-

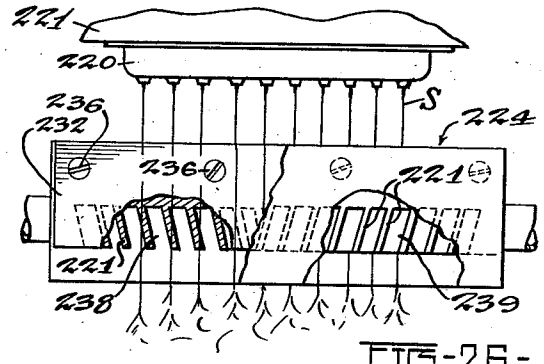


FIG-26-

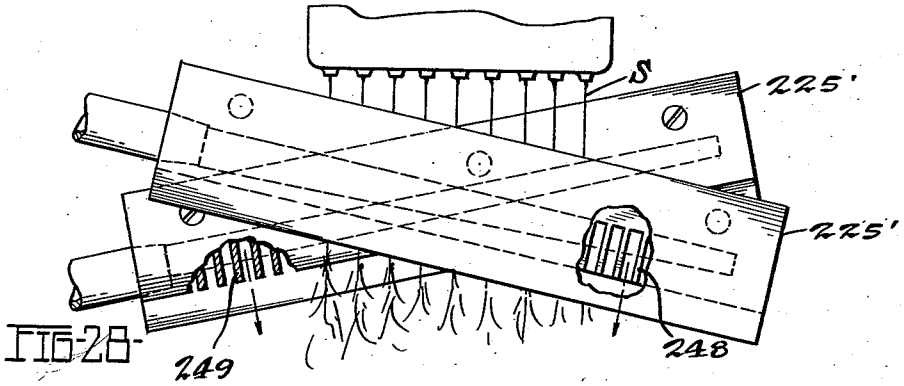


FIG-28-

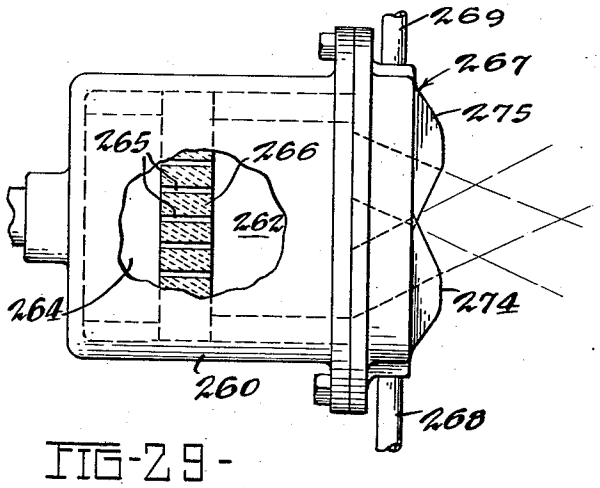


FIG-29-

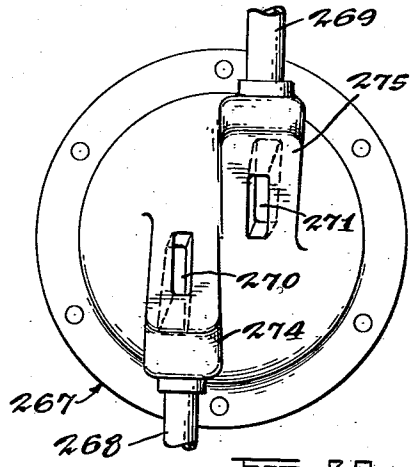


FIG-30-

INVENTORS:
GAMES SLAYTER,
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Stachi & Coleman
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Oct. 22, 1957 G. SLAYTER ET AL 2,810,157

METHOD AND APPARATUS FOR PRODUCING FIBERS

Filed March 5, 1952 10 Sheets-Sheet 9

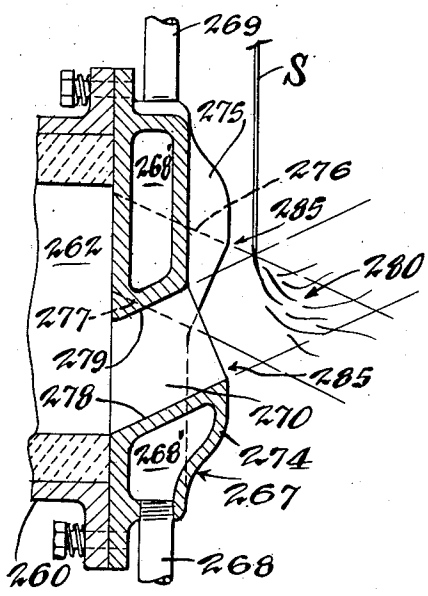


FIG-31-

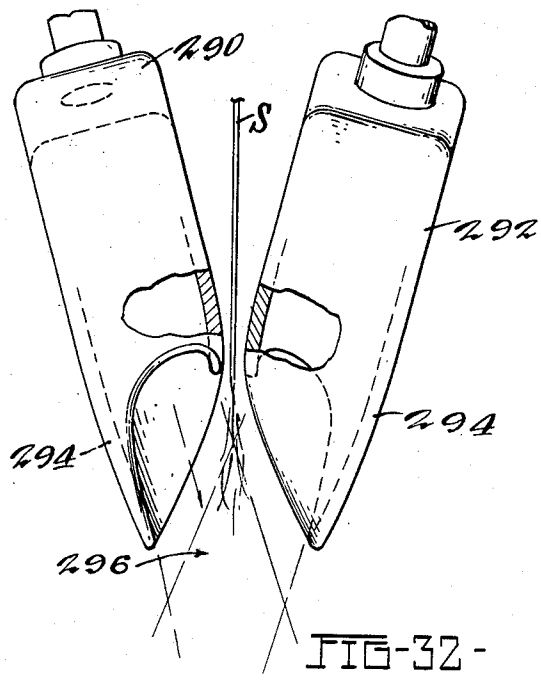


FIG-32-

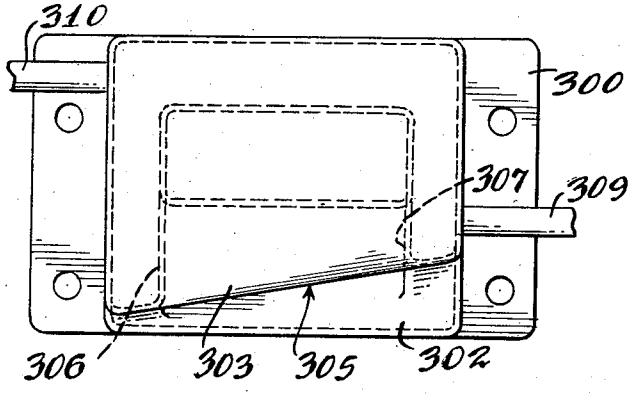


FIG-33-

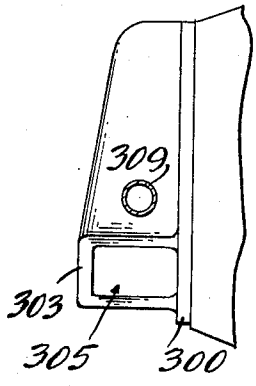


FIG-33A-

INVENTORS:
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Oct. 22, 1957 G. SLAYTER ET AL 2,810,157

METHOD AND APPARATUS FOR PRODUCING FIBERS

Filed March 5, 1952 10 Sheets-Sheet 10

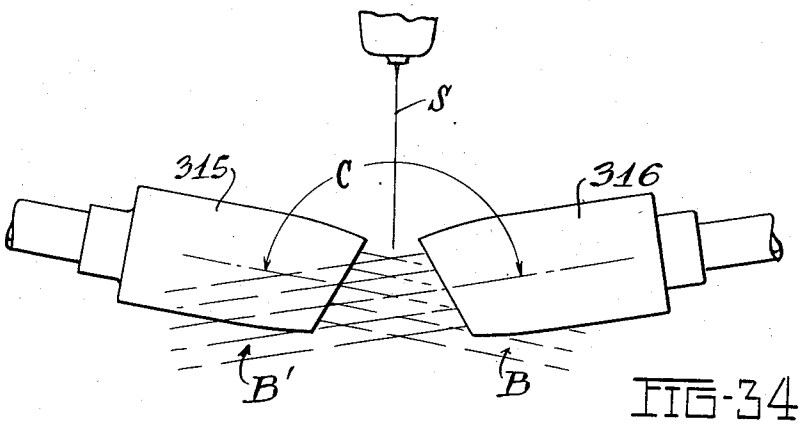


FIG-34-

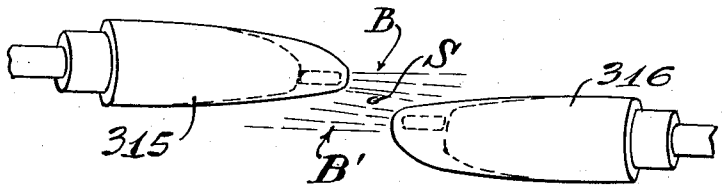


FIG-35-

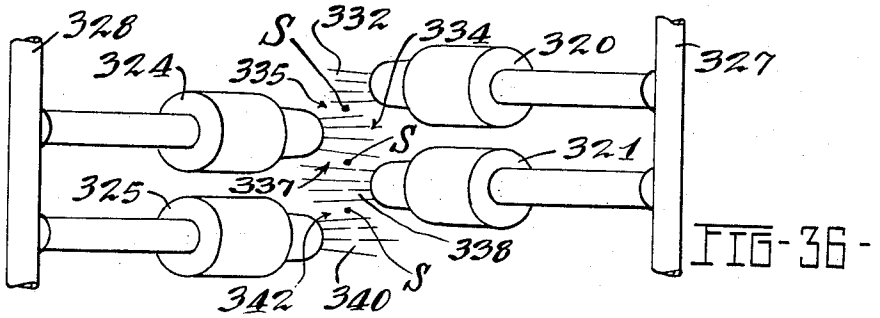


FIG-36-

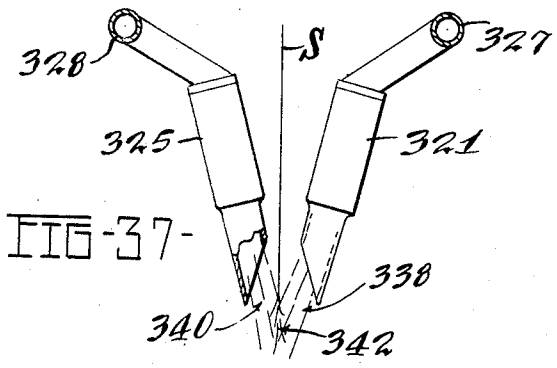


FIG-37-

INVENTORS:
GAMES SLAYTER.
BY ED FLETCHER.
Starkin & Coleman
ATTORNEYS.

United States Patent Office 2,810,157
Patented Oct. 22, 1957

2,810,157

METHOD AND APPARATUS FOR PRODUCING FIBERS

Games Slayter and Ed Fletcher, Newark, Ohio, assignors to Owens-Corning Fiberglas Corporation, Toledo, Ohio, a corporation of Delaware

Application March 5, 1952, Serial No. 274,912

24 Claims. (Cl. 18—2.5)

This invention relates to a novel method and apparatus for converting, reducing or changing materials to a finely divided state or condition, the method involving a novel utilization of forces acting on materials in a manner to fiberize, atomize or otherwise effect changes in the physical character or state of division of materials.

The invention relates more especially to a novel method and apparatus for converting or changing flowable materials into fibers or to a state of fine subdivision such as the conversion of heat-softenable mineral materials such as glass, fusible rock or slag to fine fibers, or for forming fibers from other materials such as fiber-forming resins or the like, for atomizing liquids and for disintegrating other materials by trituration through the application of forces in the manner of the present invention.

The present invention has been found to have particular utility in converting bodies of glass to fine fibers and hence the detailed application of the method and apparatus for such purpose is herein emphasized as a preferred example in carrying out the principles of the invention which as hereinafter explained are readily applicable in processing other materials.

The formation of fibers from such materials as glass, fusible rock or slag, has been carried on commercially for several years and fibers formed from these materials have been utilized extensively for sound attenuation, heat insulation and other allied purposes as mineral fibers possess many advantages over vegetable fibers. They are verminproof, are not subject to deterioration under adverse weather conditions, are incombustible and hence are ideally suited in installations where the liability of fire presents a dangerous hazard.

Fibers for these purposes have been heretofore produced from minerals by directing blasts of steam or compressed air against a plurality of fine streams of molten mineral material, the steam or air blasts drawing out or attenuating the fine streams into fibers. Fibers formed by this process are however comparatively coarse, of indiscriminate lengths and the fibrous end product, such as a mat or bat, usually contains a high percentage of shot or pellet formations of unfiberized material. In some cases, the percentage of shot by weight in the fibrous mass may be well above 40% and usually averages between 35% and 40%, depending upon the particular operating conditions. The existence of pellets or unfiberized material in the end product serves no useful purpose as such pellets have practically no insulating value and merely increase the shipping weight of mat structures formed of the fibers. Such processes have been extensively used

commercially because of the ability to attenuate a large number of streams of glass by a single apparatus although the fibers are somewhat coarse in character.

Another method that has been utilized to some extent for producing fibers of much finer character than those produced by the steam or air blast method involves the use of a blast of intensely hot gases extruded from a burner, the fiber-forming material being conveyed into the blast in a rod-like or rigid condition. A blast of this character is formed by projecting exhaust or burned gases through a comparatively small or restricted orifice in a wall of a burner in which a combustible mixture is burned at a constant rate to produce a great expansion of the gases resulting in an intensely hot, high velocity blast.

The rods or primary filaments of glass or the like conveyed or fed into a blast of this character are softened and attenuated by the velocity of the blast to extremely fine fibers, the fibers being of an average size of from one-half to five microns in diameter. Due to certain limitations characteristic of this process, endeavors to increase the economical production of fine fibers by attenuation of primary filaments have not been entirely satisfactory. Attenuation of fibers by the use of a hot blast of gas has certain advantages in that the resulting product contains a comparatively low percentage of unfiberized material or pellets as well as the attainment of a fluffy resilient fibrous mat of fine fibers endowed with an improved insulating factor as compared with mats formed by the steam blast method. Methods have been explored directed to the utilization of a stream of molten glass fed directly into an intensely hot blast by utilizing differential pressure of a controlled stream of air induced by the blast to cause the glass stream to enter the blast and therein attenuate to fibers, but methods of this character have had only limited use because of the low fiber production in proportion to the heat energy expended resulting in increased cost of producing fine fibers on a commercial scale. To obtain attenuated fibers through feeding a stream of molten material into a blast, it has been heretofore essential to feed the stream in a manner providing a nub or inertia zone from which the gases moving at high velocity may draw the stream into fibers.

The present invention embraces a novel method involving a new principle of application of forces operative upon materials for producing fine fibers wherein one or more streams of flowable fiber-forming material of substantial size or volume may be converted or transformed into fine fibers whereby a high rate of fiber production is obtained compared to the energy input of the fiber-forming forces.

An object of the invention involves the establishment and application of forces acting in diverse directions upon a body of material in such a manner that the body is broken up by the forces into particles or globules which are immediately converted to fine fibers by the forces.

An object of the invention resides in the provision of a method of transforming or converting heat-softened materials to fiber form by subjecting the softened materials to forces acting in different directions at velocities sufficient to fiberize the materials with a minimum of unfiberized material in the end product.

Another object of the invention embraces a method of efficient utilization of energy in the form of forces

operative at comparatively high velocities in directions forming in effect force couples into which a flowable material is delivered whereby the velocities of the forces disintegrate or transform the material to a finely divided state or condition with a high degree of energy efficiency.

An object of the invention resides in providing a plurality of streams of gas moving at high velocities and flowing in an angular relationship whereby a body of softened fiber-forming material is acted upon by the streams in a manner reducing the material to fine fibers of which a substantial proportion is of a size one micron or less in diameter.

Another object of the invention resides in a method wherein a plurality of gaseous streams moving at high velocities are arranged for traverse in directions forming an X-pattern and includes feeding a body of material into the crossover zone of the blasts whereby the forces of the blast in angular relationship create a turbulence acting upon the material to reduce the same to fiber form by attenuation, attrition or other disintegrating or fiberizing action.

A further object embraces a method of transforming material to a finely divided condition or state resulting in an end product comprising a mass of comparatively fine fibers with a minor amount of unfiberized material most of which appears in flake-like particles and fine dust providing a fibrous mass of comparatively low density.

Another object embraces a method and apparatus especially usable for fiberizing mineral material wherein the end product is inclusive of a large percentage of very fine fibers of lengths sufficient to impart a high degree of resiliency to the fibrous mass.

Another object of the invention relates to the method of delivering a stream of fiber-forming material into a zone of high velocity forces in a manner such that a coupling is established between the stream and the forces whereby under the influence of the forces the mechanically unstable stream is disintegrated or broken up into small bodies which under the influence of the forces are instantly attenuated or otherwise formed into fibers.

Another object of the invention embraces a method of converting fiber-forming material to fine fibers especially adaptable for large-scale production wherein large quantities of material are formed into fibers in a minimum of time, the operation being continuous and the apparatus for carrying out the method requiring less space than apparatus heretofore used for securing a comparable yield of coarse fibers.

Still another object is the attainment of a method of forming fibers of very fine character adaptable for large-scale commercial operations wherein large amounts of energy per unit of time are expended in the form of heat and extremely high velocities which have been found necessary to secure a high fiber yield, such state or operating condition being herein referred to as a high energy level.

Further objects and advantages are within the scope of this invention such as relate to the arrangement, operation and function of the related elements of the structure, to various details of construction and to combinations of parts, elements per se, and to economies of manufacture and numerous other features as will be apparent from a consideration of the specification and drawing of a form of the invention, which may be preferred, in which:

Figure 1 is a semi-diagrammatic elevational view illustrating one form of apparatus for carrying out the method of the invention;

Figure 2 is a sectional view taken substantially on the line **2—2** of Figure 1;

Figure 3 is a diagrammatic view illustrating an angular relationship between orifices from which flow the fiberizing gaseous blasts;

Figure 4 is an elevational view illustrating structural features of one form of apparatus for carrying out the method of the invention;

Figure 5 is a side elevational view of the apparatus illustrated in Figure 4, one of the burner constructions being illustrated in section;

Figure 6 is a top plan view of the burner arrangement illustrated in Figure 4, showing one form of adjusting means for the burner construction;

Figure 7 is a front elevational view of one of the burner orifices, the view being taken on the line **7—7** of Figure 4;

Figure 8 is a detailed sectional view through the blast orifice, the view being taken substantially on the line **8—8** of Figure 7;

Figure 9 is a diagrammatic view illustrating the path of movement of the body of fiber-forming material under the influence of the gaseous blasts in the use of the apparatus shown in Figure 1;

Figure 10 is a semi-diagrammatic elevational view illustrating blast-forming means arranged in a generally vertical position wherein the axes of the blasts are aligned with the respective blast-forming means;

Figure 11 is a side view of the apparatus illustrated in Figure 10;

Figure 12 illustrates another position of blast-forming means wherein the mean axis of the crossed blasts is substantially horizontal;

Figure 13 is an elevational view of apparatus for producing crossed blasts moving in substantially parallel horizontal planes and showing methods of feeding rods or primary filaments of fiber-forming material into the crossover zone of the blasts;

Figure 14 is a top plan view of the arrangement shown in Figure 13, the view being taken upon the line **14—14** of Figure 13;

Figure 15 is a view similar to Figure 7 illustrating a modified form of blast-directing orifice, portions being shown broken away for purposes of illustration;

Figure 16 is a vertical sectional view taken substantially on the line **16—16** of Figure 15;

Figure 17 is a sectional view through the orifice construction, the view being taken on the line **17—17** of Figure 15;

Figure 18 is an elevational view showing another form of an orifice plate construction associated with a blast-forming means for directing gaseous blasts in crossover relation;

Figure 19 is a sectional view taken substantially on the line **19—19** of Figure 18;

Figure 20 is a bottom plan view of the blast orifice construction shown in Figure 18;

Figure 21 is an elevational view of a modified form of blast-forming means wherein dual blasts projected in crossover relationship emanate from a single chamber;

Figure 22 is a front elevational view of the burner shown in Figure 21;

Figure 23 is an elevational view illustrating a modified structural arrangement of blast-producing burners, particularly showing an adjustable mounting means for the burners;

Figure 24 is a side view of the burner construction and mounting means illustrated in Figure 23;

Figure 25 is a top plan view of the arrangement shown in Figure 24;

Figure 26 is an elevational view illustrating a blast orifice construction especially adapted for use with a high velocity steam or air blast wherein the nozzle is formed with angularly disposed blast-directing slots;

Figure 27 is a sectional view of the arrangement illustrated in Figure 26;

Figure 28 is a view similar to Figure 26 illustrating the blast orifice means arranged in angular relation to provide crossed blasts;

Figure 29 is a fragmentary elevational view of a burner similar to that shown in Figure 21 provided with a modified form of orifice construction for establishing crossed blasts;

Figure 30 is a front view of the orifice construction illustrated in Figure 29;

Figure 31 is a partial sectional view through the burner construction illustrated in Figure 29;

Figure 32 shows dual burners for producing angularly related blasts embodying the blast orifice configuration of the character shown in Figure 28;

Figure 33 is a view similar to Figure 7 embodying an orifice construction having the operating characteristics of the type shown in Figure 28;

Figure 33*a* is an end view of the construction shown in Figure 33;

Figure 34 is a diagrammatic elevational view showing dual blasts crossing one another wherein the blasts travel substantially in opposed directions;

Figure 35 is a top plan view of the arrangement illustrated in Figure 34;

Figure 36 is a top plan view of apparatus for producing a multiplicity of blasts arranged to provide a plurality of crossover zones, and

Figure 37 is an elevational view on a reduced scale of the arrangement shown in Figure 36.

The principle of operation of the method of the present invention resides in the establishment and utilization of forces acting along divergent loci upon flowable materials to fiberize, reduce, transform or disintegrate the materials to fibers or other finely divided form or condition. The method of the invention may be carried out by utilizing gases or other fluid mediums moving at high velocities and with sufficient force or kinetic energy to attenuate, attrite or convert materials to fine fibers or other form of subdivision. The method is especially suitable for transforming heat-softenable materials to fibers through the utilization of high velocity gaseous blasts and particularly heat-softenable mineral materials such as glass, slag, argillaceous rock or calcareous rock to fiber form and may also be used to advantage in forming fibers from heat-softenable resinous materials.

The blasts may be formed of intensely hot gases moving under high velocities such as the products of combustion resulting from burning combustible mixtures in confined zones and the hot gases discharged through restricted orifices to attain high velocities. Gases such as steam or compressed air may be utilized to advantage in carrying out the present method in a manner hereinafter described.

Under certain operating conditions of the present method, the fiber-forming materials may be in a highly fluid condition and under other conditions, the material may be of a more viscous nature. Under certain operating conditions, fiber-forming material may be fed into the fiberizing zone of the blasts in a substantially solid state.

While the method of the invention has been found to be especially applicable in forming fine fibers from mineral materials such as glass, the principles of operation may be employed in transforming or disintegrating other materials through the utilization of divergently acting forces in the manner hereinafter described.

Referring to the drawings in detail and first with respect to the form of apparatus illustrated in Figures 1 through 8 inclusive for performing or carrying out the steps of the method, the apparatus disclosed is particularly adaptable for converting or attenuating bodies of heat-softenable, fiber-forming material to fibers. As glass in a molten or softened state is readily converted to fibers by the method of the invention, the apparatus will be described in connection with its use for converting glass to fibers. The arrangement illustrated in Figures 1 and 2 includes a forehearth **10** adapted to contain a supply of glass or other fiber-forming material in a heat-softened or flowable condition, the forehearth being connected with a suitable melting furnace (not shown). Disposed beneath the forehearth **10** is a feeder or bushing **12** having one or more orifices or outlets located in a lower wall thereof from which flow streams S of molten glass.

The glass streams are engaged by forces operative in divergent directions upon the flowing body of material or glass to transform it to fine fibers. In the form of the invention illustrated in Figure 1, the forces acting upon the glass streams are in the form of intensely hot gaseous blasts provided by products of combustion discharged from internal combustion burners adapted to burn a fuel and air mixture. The burners are indicated at **14** and produce blasts discharged through orifices arranged at the forward extremities of the burners, the temperature of the gaseous blasts being above the softening temperature of the glass. The burner constructions and their mounting arrangements will be hereinafter described in further detail.

The blasts discharged from the burners **14** engage the molten stream of glass and by reason of the high blast velocities and the angular relationship of the blasts, the molten material is attenuated, triturated or otherwise converted or transformed to fibers F which may be confined within a hood **17** and collected at a suitable fiber-collecting zone **18**. As illustrated in Figures 1 and 2, the fibers may be deposited and collected upon the upper flight **20** of an endless conveyor **21** supported by suitable rollers **23**. The endless belt conveyor in the embodiment illustrated may be actuated so as to move the upper flight **20** in a left-hand direction as viewed in Figure 2 so that the fibers F which are continuously formed and collected upon the conveyor **20** may be carried away from the collecting zone for further processing. Disposed beneath the upper flight **20** of the conveyor is a chamber **25** which is connected with a suitable source of reduced pressure or suction to facilitate the deposition and accumulation of the fibers upon the conveyor flight **20** and to aid in carrying away the heat of the blasts.

It may be desirable to treat the fibers during formation with a lubricant or other coating as the fibers are formed. To accomplish a treatment of the fibers, there may be provided nozzles or applicators **27** projecting interiorly of the forming hood **17** for directing the fiber-treating lubricant or coating onto the fibers as they move through the forming hood.

For certain uses and purposes, it is desirable that the accumulated mass or mat of fibers M be treated with a bonding resin or other suitable material for imparting mass integrity to the fibrous mat. Bonding resin of this character may be sprayed or deposited upon the fibers by means of one or more applicators **29** disposed exteriorly of the forming hood **17** and adjacent the path of the moving mass of newly formed fibers.

One form of structure of blast burner arrangement of the invention and supporting arrangement is illustrated in detail in Figures 4 through 8 inclusive. This structure is inclusive of a frame **35** formed of base members **36** and a pair of upwardly extending columns **38** reinforced by struts or braces **39**. Secured to each of the columns **38** is a tubular structure **41** within which is slidably disposed posts **42** which are secured at their upper extremities to a platform member **44** in the form of an inverted channel member.

Means is provided for raising and lowering the posts **42** and platform **44**. As shown, a horizontal shaft **46** is mounted in suitable journals carried by the uprights **38** and is equipped with spur gears **48** enmeshed with the teeth of a rack **49** secured to each of the members **42**. A handwheel **50** is provided for rotating the shaft **46** and gears **48** to elevate or lower the platform **44**. A suitable locking means (not shown) may be associated with the shaft **46** and gears **48** to retain or lock the posts **42** in adjusted positions.

The platform **44** supports members **52** which are bored to receive rods or ways **54**. The rods **54** form supporting means for a pair of carriages **56** and **57**. The carriages are of substantially identical construction, each being formed with a base member **58** provided with a

depending portion 59 bored to receive the supporting shafts 54. The carriages are adapted to be moved toward and away from each other to vary the horizontal distance between the burners 14. Each of the carriages is formed with vertically extending members 60 joined at their upper ends by plates 61.

Extending upwardly from the platform 44 are spaced members 63 having openings to accommodate a shaft 65, the latter being arranged in parallelism with the shafts 54. The shaft 65 is formed with spaced enlarged threaded portions 67, one of right-hand threads and the other of left-hand threads, which respectively cooperate with a third member 69 secured to the upright member 60 of each carriage. The ends of the shaft 65 are provided with polygonally shaped or squared portions 71 adapted to receive a suitable crank or wrench for rotating the shaft 65. By reason of the right and left threads on shaft 65, rotation of the shaft in one direction moves the carriages 56 and 57 toward each other while rotation of the shaft in the opposite direction moves the carriages away from each other.

Each of the carriage constructions 56 and 57 provides a supporting means for a trunnion or shaft 74 which extends through bearing members 75 secured to the uprights 60 in order to provide a substantial mounting for the trunnion 74, the latter being revoluble in the members 75. Secured to each trunnion or shaft 74 is a member or shaft 78, the trunnions 74 and members 78 being formed at adjacent ends with flanges 79 and 80 as shown in Figure 5. The opposite end of each of the members 78 is formed with a semi-annular portion 82 which cooperates with a semi-annular member 83 to support a burner construction. Each semi-annular portion 82 and a member 83 are secured together by means of bolts 84 to rigidly clamp and support the adjacent burner 14. Each of the trunnion shafts 74 is provided with a worm wheel 86 driven by a worm 88 mounted upon a shaft 90 of squared or polygonally shaped cross-section. The central openings in the worms 88 are of reciprocal shape in cross-section to that of the shaft 90 so that during relative movement of the carriages 56 and 57 along the supporting rods 54, the worms 88 are relatively slidable along the shaft 90. Due to the non-circular drive connection between the drive shaft 90 and the worms 88, rotation of the shaft 90 rotates the worms to drive the worm wheels 86 and thereby effects corresponding rotation or angular positioning of each burner 14 about the axis of its supporting shaft 74. Rotation of the shaft 90 to adjust the relative angular positions of the burners 14 about the shafts 74 may be effected by applying a suitable wrench or crank to an extremity of the shaft 90.

As shown in Figure 5, each of the burners 14 is supported in the semi-annular members 82 and 83 which are secured in clamping relation about the burners by securing means 84. By backing off the nuts 85 on the bolts 84, the burners 14 may be individually rotated about their longitudinal axes to establish an angular relationship of the orifices from which the blasts emanate to establish the desired relative angular or crossover positions of the blasts.

The burners 14 are of the so-called internal combustion type adapted to burn a combustible mixture of fuel and air, the products of combustion being discharged from the burners to provide high velocity gaseous blasts. A burner of this general character is disclosed in Slayter and Fletcher Patent No. 2,489,242. Each burner construction includes a metal shell 95 which is lined interiorly with suitable refractory material 97 as shown in Figure 8. The refractory material 97 surrounds and forms a combustion chamber 98 providing a confined zone within which combustion takes place.

As shown in broken lines in Figure 6, the rear wall 99 of the combustion chamber 98 is formed with a plurality of small apertures or passages 100 through which a fuel and air mixture supplied to a manifold 101 by an inlet pipe 102 is caused to enter the combustion chamber 98 by the pressure applied to the fuel and air mixture. The fuel may be a natural or artificial gas or other combustible. The fuel and air are introduced into the burners under a comparatively low pressure as, for example, five pounds per square inch, although other pressures may be employed if desired.

The products of combustion are discharged from the burners through restricted orifices to form intensely hot blasts of relatively high velocities. As particularly illustrated in Figure 8, an orifice plate or member 105 is secured to the front end of each burner and is provided with an opening or passage 106 through which the gases are projected from the chamber 98. The discharge orifice 107 is bounded by walls 108 and 109 projecting downwardly and at a slight angle with respect to a vertical plane. The walls 108 and 109 are shaped to register with the passage 106 in the plate 105. The orifice construction is arranged to be cooled by a suitable medium and includes a chamber 111 surrounding the orifice 107 and is provided with an inlet pipe 113 and an outlet pipe 114. The pipes are adapted to convey a cooling liquid such as water or a gas through the chamber 111 in order to reduce the temperature of the orifice walls.

The orifice construction is preferably removably secured to the burner by bolts or other means passing through openings 115 in the plate 105. As shown in Figure 7, the orifice 107 is preferably of elongated rectangular cross-section to provide a ribbon-like gaseous blast of high velocity. The burning of a combustible fuel and air mixture within the chamber or confined zone 98 produces a blast of intensely hot gases, the temperature of the gaseous blast or products of combustion being upwards of 3000° Fahrenheit, well above the softening temperature of the glass or other heat-softenable material which is transformed by the blasts into fibers.

As illustrated in Figures 2 and 3, the orifices 107 are angularly disposed and spaced apart so that the gaseous blasts are projected downwardly in generally parallel planes and at relative angularities causing them to cross each other in brushing relation at a zone at which the fiber-forming material or glass is introduced or delivered to be acted upon by the forces of the high velocity blasts. The burners 14 are adjustable to vary the distance between the blast orifices, to change the relative angularities of the blasts and to move the blast-forming means vertically relative to the molten glass stream or other fiber-forming material. The burners 14 are adjusted in a vertical direction by elevating or lowering the platform 44 carrying the burner-supporting means by manipulation of the handwheel 50 to rotate the gears 48 and actuate the racks 49. By this means, the crossover zone of the gaseous blasts may be adjusted toward or away from the stream feeder 12 to obtain the most efficient point of delivery of the fiber-forming material into the blasts.

The horizontal spacing of the burners 14 and hence the extent or degree of brushing contact of the blasts may be regulated by rotating the shaft 71 to move the burner-supporting carriages 56 and 57 in horizontal directions. The relative angularities of discharge of the blasts from the burners 14 toward each other may be changed by rotating the shaft 90 actuating the worms 88 and worm wheels 86 to effect rotation of the burners 14 about the axes of the trunnion shafts 74. By this arrangement, the angularity at which the blasts are brought into brushing relation may be adjusted to secure the most efficient fiber formation.

The relative divergence of the gaseous blasts in establishing a desired crossover relation may be varied by changing the relative angular positions of the orifices or blast-discharge outlets. As shown in Figure 3, the angle A represents the divergent angle of crossover of the blasts. It has been found that a relative included angle of divergence of the crossed blasts indicated by the angle A in Figure 3 of from 20° to 35° has been found to produce

a satisfactory and desirable fibrous mat having a high percentage of fine fibers of a length suitable to impart resilience to the mat. Through the adjustable mounting arrangements for the burners **14**, the latter may be positioned at various angles of crossover for the blasts or the crossover zone at which the blasts brush or contact one another may be modified or varied as desired.

The glass stream or streams S, which are comparatively large, pass between the orifice constructions shown in Figure 1 and into the influence of the high velocity gas streams. Figure 9 is diagrammatically illustrative of the approximate locus or path of the molten glass stream as it moves from its vertical flow path into the influence of the blasts. From visual inspection, the stream appears to first follow a wavering path and is then deflected laterally by reason of the differential pressures established by the high velocities of the blasts and their divergent paths. The stream of fiber-forming material appears to be rotating or oscillating at a zone adjacent the outlets of the orifice constructions and resembles a mushroom-like formation **122**, a state or condition probably caused by the divergently acting forces or force couples acting on the glass stream as it enters the turbulence existing in the crossover zone **123**.

The tremendous yield of fine fibers, some of which are believed to be the finest fibers ever produced, obtained from the practice of our novel method of fiber formation evidences a phenomenon of operation in the production of fibers which is completely different from any prior methods. Heretofore very fine streams of glass or fiber-forming material were necessary to secure attenuated fibers by the steam blast method and comparatively fine rods or filaments of about twenty-thousandths of an inch in diameter have been used with the hot blast methods to secure fiber attenuation. The limitations of the amount of material fed to the attenuating blast necessarily restricted the fiber yield.

The method of this invention is particularly adaptable to efficiently fiberizing large quantities of fiber-forming material in a given unit of time resulting in a yield of very fine fibers many times that obtainable from other methods of hot blast fiber formation. One or more streams of glass of a diameter of one-quarter of an inch or more are readily and efficiently converted to fine fibers by the forces utilized in the manner of the present invention.

We attribute the attainment of the phenomenal yield of fine fibers to the novel principle of fiberization through the employment of crossed blasts of tremendous velocities and the utilization of large amounts of kinetic energy.

As the glass stream moves downwardly and enters the crossover zone into the turbulence established through the brushing relation of the blasts, the violent forces in said zone act on the liquid stream to disrupt the stream and disintegrate it into a large number of liquid particles or bodies. This action takes place because the stream, being liquid, is mechanically unstable and under the influence of the force couples established by the divergently-acting, high velocity forces, the stream is torn or broken up into particles. Thus there is established a coupling between the high velocity, divergently directed gaseous blasts and the glass stream whereby the forces act to break up the stream. The particles, bodies or fragments, being in liquid form, are virtually exploded by the forces into fine fibers or are attenuated to fibers by the divergently-acting forces of the blasts. Through the utilization of large amounts of kinetic energy by burning substantial quantities of combustible mixture in the burners and discharging the intensely hot gases of combustion at high velocities and delivering the glass in a highly fluid condition to the crossover zone, the high temperature working range is increased so that attenuation of the particles occurs throughout the working range with the glass remaining in fluid form. Hence the bulk of the particles are drawn or attenuated to fibers of a fineness not heretofore obtainable by conventional methods.

While it has been found that a small portion of the glass delivered to the blasts may not have been converted to fiber form, a substantial amount of such unfiberized residue in the fibrous end product is in the form of flakes or bodies of minute dimension having planar surfaces or facets. Some of the unfiberized material is in the form of fine dust with a minor amount of small shot or pellets present in the end product. Heretofore the unfiberized component of a fibrous mass appeared in the form of shot or pellets in those fiberizing processes of a commercial character employing steam or air blasts. By actual tests, it has been found that in end products of fibrous mineral material formed by steam or air blast methods, the shot or pellet content may be upwards of thirty-five or forty percent by weight of the fibrous end product. In the end product formed by the method of this invention as carried out through the use of the apparatus illustrated in Figures 1 through 9, the unfiberized material in the end product may be reduced to less than fourteen percent by weight of the complete product with the bulk of unfiberized material appearing in the forms of dust or minute flake-like particles.

The avoidance as far as possible of unfiberized material in the end product is extremely important for several reasons especially where the fibrous product is used for heat insulation or acoustic purposes. The unfiberized material performs no useful function whatever and increases the manufacturing and material costs of the fibrous products as well as the transportation costs because of the added weight of glass in unifiberized condition.

While the action of the many forces operating in the blasts in converting flowable material to fiber form or fine particle size may not be fully comprehended, the actual operation of the apparatus in carrying out the method results in the production of a fibrous end product having a high percentage of fine fibers and a low constituent of unfiberized particles. The formation of shot or pellets is greatly reduced in the process. The relative angularity or included angle of divergence of the blasts has a material bearing upon the fineness of the fibers produced and the amount of unfiberized residue in the end product as shown by the results of actual operations hereinafter described.

From actual tests it has been found that extremely fine fibers are most satisfactorily formed from glass while the latter is in an extremely fluid condition. This may possibly be attributed to the fact that glass at a very high temperature remains in a fluid or fiber-forming condition for a longer period of time while it is being acted upon by the forces of the high velocity blasts. If fibers of increased diameters are desired, the temperature of the glass may be lowered to increase the viscosity of the glass. The character of the fibers may be varied by moving the blast-producing means or burners closer to or farther away from the source of the fiber-forming material. By proper correlation of these and other operating factors, the method provides for the maintenance of an effective and efficient control over the character and size of fibers produced.

The desired relative positioning of the blasts, their angles of incidence and their angles of divergence or crossover may be determined through the adjustable mounting means or devices associated with blast-producing means. The burners **14** may be elevated or lowered with respect to the glass feeder **12** by manipulation of the handwheel **50**, the gears **48** enmeshed with the racks **49** serving to elevate or lower the burner constructions supported upon the table **44**. The angle of incidence of one blast toward the other may be varied by rotating the burners about the axes of shafts **75**. This adjustment is attained by affixing a suitable tool to one end of the squared shaft **90** and rotating the shaft to cause rotation of the worms **88**,

worm wheels 86 and shafts 75 and 78 directly supporting the burners or blast-producing means 14.

The juxtaposed relationship of the blasts or their horizontal spacing may be varied by moving the burners toward or away from each other by applying a suitable tool to the shaft 65 and rotating the same in the proper direction to thread the nuts 69 along the shaft to move the burner assemblies along their aligned horizontal axes. The amount of relative angularity or divergence of the blasts may be adjusted or varied by manipulating the clamp screws 84 to release the clamps 82 and 83 surrounding the burner housings. The burners may then be manually rotated about their horizontal axes until the proper lateral angularity or divergence of each blast is obtained with respect to the other. The relative angular positions of the burners may be maintained by drawing the clamps 82 and 83 into frictional contact with the cylindrical outer surfaces of the burner housings.

The blasts in their opposed relation are preferably projected in substantially parallel planes but with a sufficient angle of incidence so that the gas streams contact or brush one another at the crossover zone into which the fiber-forming material may be delivered to be acted upon or converted to fiber form. While the blasts are directed in substantial parallelism in crossover or X-like relation, brushing contact of the surface layers of the gas streams is established without appreciable intersection so as to avoid interference or interruption of the individual paths of the streams and maintain high blast velocity necessary to secure efficient attenuation or formation of fibers.

The fiber-forming material is preferably introduced at the zone of crossing of the blasts where it is subjected to divergently acting forces attaining the phenomenal efficiency of attenuation or fiber formation of this process. The fiber-forming material moving into the zone of turbulence between the blasts is disintegrated or separated into relatively small components, most of which are exploded, attenuated or otherwise converted by the high velocities to fiber form. Only a relatively small proportion of the fiber-forming material remains in unfiberized condition in contradistinction to the high percentage of shot-like or pellet formations of unfiberized material occurring in the end products produced by conventional blast processes where the blasts are not directed in crossing relation.

The method of the invention carried out through the utilization of the apparatus illustrated in Figures 1 through 9 results in a product in the form of a mass or mat of haphazardly arranged fibers wherein substantial quantities of the fibers in the mass are of extremely fine size. Tests of fibers from three sample runs of the apparatus showed the following average fiber diameters ascertained through the use of the electron microscope:

Test	No. of Fibers	Average Diameter in Inches
No. 1	180	.0000170
No. 2	120	.0000146
No. 3	220	.0000156

In these and other groups of fibers produced by the method of the present invention, it was found that fiber diameters ranged from one millionth of an inch to twenty-four hundred thousandths of an inch with a large portion of the fiber diameters being less than one hundred thousandth of an inch.

Another factor that appears to be of vital importance in securing efficient and economical production of fibers in the process is the establishment of operating conditions involving a so-called high energy level. It has been found by tests that a high blast velocity of comparatively small volume of gas does not result in efficient attenuation of fiber-forming material. Efficient and economical operation is dependent in a large measure upon the employment of gaseous blasts in crossover relation wherein comparatively large quantities or volumes of gas are provided in forming the blasts moving at high velocities in order to attain a high energy level. The following are typical examples of actual operating conditions in carrying out the process of the invention. The apparatus included two internal combustion burners of the type shown at 14 in Figure 1 equipped with rectangularly shaped orifices of the character shown in Figures 7 and 8, each orifice being three inches long and seven-sixteenths of an inch in width. The burners were adjusted to secure a combined combustion rate of fourteen hundred and fifty cubic feet of fuel gas per hour under an input pressure of four and three-quarters pounds at the manifolds of the burners. The blasts established by these operating conditions produced a high yield of fine fibers from large streams of molten glass.

By equipping the burners with rectangularly shaped orifices, each orifice being three and three-quarters inches in length and one-half of an inch in width, the burners consumed a total of two thousand cubic feet of fuel gas per hour under an input pressure at the manifolds of four and three-quarters pounds per inch. The blasts provided under these operating conditions resulted in a high yield of fibers which are on the average of slightly smaller diameter than those obtained under the first-mentioned operating conditions, probably due to the increase in blast energy expended. The operating conditions above-described result in the attenuation or conversion of glass batch to fibers at rates of one hundred pounds or more per hour.

The angle of divergence of the crossing blasts has a definite effect upon the amount of unfiberized glass in the end product appearing in the form of flake-like particles. For example, actual tests under operating conditions of the character described gave the percentage by weight of unfiberized material when the blasts were crossed at the specified included angle of divergence as listed below:

Included Angle of Divergence of Blasts	Percent by Weight of Unfiberized Glass in End Product
Zero Angle	41.75
8°40′	37.07
13°	36.73
17°20′	25.31
26°	13.28
30°20′	

From the foregoing, it will be seen that increasing the divergence angle from 17° 20′ to 30° 20′ resulted in a substantial reduction in the amount of glass in an unfiberized state in the end product. The temperature of the molten glass at the stream-feeding means is maintained at or above 2500° Fahrenheit in order to deliver the glass in a highly fluid or flowable condition into the crossover zone of the blasts. Utilization of the glass in a highly fluid state results in longer fibers being formed, and the presence of comparatively long fibers in the mass or mat enhances the resilient characteristics of the product. This is a desirable factor, especially where the mats are employed for heat and sound insulation purposes.

Moreover, the fiber-forming operation of the present method is not of a critical nature as the high velocities and high energy level of the dual blasts in crossed relation provide divergently acting forces and the twisting or swirling forces in the crossover zone that are adequate to convert large quantities of fiber-forming material to comparatively fine fibers in a given unit of time. Hence with ample blast velocities and a relatively large amount of energy available as kinetic forces in the blasts, a single stream of fiber-forming material of substantial size or a plurality of streams may be fed or delivered into the zone of contact or crossover of the blasts and successful fiber

formation obtained avoiding critical operating factors and precision adjustments that are attendant the commercial utilization of other fiber-forming processes adapted to produce fibers of a comparable nature and size.

Figures 10 and 11 illustrate a form of apparatus for carrying out the method of fiber formation wherein the blast producing means or burners are arranged in substantially vertical relation. The apparatus is inclusive of a pair of burners **125** or other instrumentalities for producing or establishing high velocity forces adapted to act upon fiber-forming materal. The burners **125** are of generally the same construction as the burners **14**. Each is formed with an interior chamber **127** into which a mixture of fuel and air or other combustible mixture is admitted through tubes or manifolds **128**. Each chamber **127** terminates in a restricted orifice **130** of elongated character arranged to project a blast **132** in a downward, substantially vertical direction. The blasts provided by the gaseous streams emanating from the burners **125** are intensely hot gases of combustion which, by reason of their great expansion under the intense heat existent in the chambers **127** and the restricted orifices **130**, are projected from the burners at tremendously high velocities. While the gaseous blasts from the burners move downwardly, they are preferably inclined slightly toward each other as indicated in Figure 10 so that the juxtaposed surface zones of the blasts brush together or contact each other as they move in crossover relation as illustrated in Figure 11. The brushing contact of the gas streams at the zone of crossing tends to cause the gases to thereafter move in substantial parallel planes in divergent directions. The stream or body of material S is directed between the blasts at the zone of crossover as shown in Figure 10 and the forces of the blasts acting in divergent directions convert the material to fiber form.

It is to be understood that the angularity of crossover of the blasts may be varied, and it is found that as a general rule increasing the angularity of the blasts forming the crossover produces finer fibers on the average with a reduction of the material in the end product in unfiberized form as pointed out in the description of operation of the apparatus shown in Figures 1 through 8.

While it has been found preferable to utilize the crossover blasts formed of intensely hot burned gases discharged through restricted orifices at high velocities, it is to be understood that a steam blast or an air blast may be utilized as the force for converting material to fibers in a manner hereinafter described.

Figure 12 illustrates an apparatus for carrying out the method wherein the blasts cross each other as they travel at divergent angles relative to a horizontal plane. In this form the burners **125'** are disposed in an angular relation above and below a mean horizontal plane. The blasts may be formed by burned gases projected through restricted orifices of the burners **125'** at high velocity in crossed relationship and utilized for the fiber-forming phase of the method.

Where the gaseous blasts are of an intensely hot character above the attenuating temperature of glass or other heat-softenable, fiber-forming material, such blasts may be utilized to convert substantially rigid filaments or rods of fiber-forming material into fibers. An exemplification of the method of feeding or delivering rods or substantially rigid filaments is illustrated in broken lines in Figure 12. When the method is employed in this manner, one or more rods **135** may be fed between the blasts into the crossover zone by feed rolls **136** or other suitable means at a rate whereby the tips of the filaments will be continuously softened and acted upon by the blasts to convert the material to fibers. The fibers may be collected upon an upwardly moving conveyor belt (not shown) or they may be directed into a suitable collecting chamber (not shown).

Figures 13 and 14 illustrate a crossover blast arrangement in conjunction with the feeding of a rod or substantially rigid body of heat-softenable, fiber-forming material into the crossover zone of the blast at right angles to a mean or median plane bisecting the included angle of divergence of the blasts. In this arrangement the burners **125''** are disposed in positions similar to the burners of Figure 12, and a rod or rigid body **138** of fiber-forming material is directed into the crossover zone of the blasts from a substantially vertical position. The material **138** is fed or delivered to the blasts by means of feed rolls **140** or other suitable means. The rigid body **138** may be preformed from a stream of the material moved through a distance sufficient to congeal the material. The intense heat of the blasts **139** softens the tip of the body **138**, the forces of the blasts converting the softened material to fibers.

Figures 15 through 17 inclusive illustrate a modified form of burner orifice of the general character shown in Figures 7 and 8, the orifice construction being provided with guide means for imparting an angular direction to the blast. In this form of the invention, the plate **105'** supports an orifice construction provided with a plurality of tubular passages **145** forming a blast-discharge means. The orifice construction is formed with outer walls providing a chamber **111'** through which water or other cooling medium may be circulated to control the temperature of the orifice walls.

The plurality of spaced tubular passages **145** is arranged in substantial parallelism and at an angle with respect to the vertical of from 10° to 15° in order to impart an angular direction to the gases flowing therethrough forming a blast. The orifice construction secured to the opposing burner (not shown) is provided with tubular passages disposed at an oppositely directed angle. The lateral spaces **146** between the tubular passages provide for intimate contact of the cooling fluid with the walls to facilitate more uniform cooling of all portions subjected to the intense heat of the gases.

Thus burners **14** of the character shown in Figure 1 having orifice plates of the construction disclosed in Figures 15 through 17 are adapted to provide angularly divergent blasts in crossover relation without special adjustment of the burners about their longitudinal axes. If a greater or lesser angularity between the blasts is desired, the burners provided with the orifice construction of the type illustrated in Figures 15 through 17 may be rotated about their axes to secure different angular relationships of the blasts.

A further form of apparatus for carrying out the method of the invention is illustrated in Figures 18 through 20. In this form, a single burner **150** of a construction similar to one of the burners **14** is utilized for producing divergent blasts of burned gases. The burner is provided with an orifice configuration whereby the gases discharged from the burner chamber are directed through two series of openings providing two groups of gas streams moving in crossover relation for transforming material to fibers.

The blast-discharge and directing means is inclusive of a base plate **152** and a second plate **153** spaced outwardly therefrom. The plates **152** and **153** are joined by a continuous lateral or side wall **154** providing a chamber **156** adapted to accommodate a circulating cooling fluid such as water introduced through an inlet pipe **158** and carried away through a discharge pipe **159**. The plates **152** and **153** are provided with elongated openings to receive and accommodate blocks or members **161** and **162** which are welded to the plates as at **163**.

The member **161** in the illustrated embodiment is formed with a series of orifices or passages **165** preferably of circular cross-section which are disposed in substantial parallelism but are downwardly angularly inclined with respect to a horizontal plane or longitudinal axis of the burner **150**. The openings **165** in the member **161** are arranged in spaced relation in a row extending upwardly and laterally with respect to a vertical plane

extending through the center of the plate **153** and normal to the plate. The member **162** is formed with a similar row of orifices or passages arranged in spaced parallel relation but askewed or angularly directed upwardly with respect to the longitudinal axis of the burner. The group of openings **167** extend upwardly and laterally relative to a vertical plane through the center of the plate **153**. The angularly divergent rows of passages provide a generally V-shaped gas discharge orifice configuration. The passages of one row are slightly inclined toward those of the other row as shown in Figures 18 and 20.

As the rows or groups of openings or passages **165** and **167** are disposed in a converging direction, the high velocity blasts formed by the gases of combustion in the burner **150** projected through the orifices form in effect at the crossover area a V-shaped configuration or trough into which the body or stream of fiber-forming material S may be directed in the manner shown in Figures 18 and 19. As the forces of the two blasts engage the stream of material S substantially at the crossover zone, the material is heated by the intensely hot gases of the blasts and converted or transformed into fibers by the attenuating or attritive action of the blasts.

The plate **153** is formed with a wall portion **155** extending a substantial distance above the orifices **165** and **167** constituting a baffle or abutment causing the induced air stream established by the high velocities of the gases of the blasts to pass over and around the portion **155**. By directing the air stream around the plate **153**, a reduced pressure is set up adjacent the obverse face of the plate **153** in the zone immediately above the gaseous blasts flowing from orifices **165** and **167**. This reduced pressure zone influences the stream S of glass or other fiber-forming material to flow into the zone between the blasts immediately adjacent the face of the plate at the initial stage of the crossover formation. By reason of the pressure differential tending to keep the stream close to the plate **153**, the divergently directed and disruptive forces of the blasts cause the extremity of the stream of fiber-forming material to be attenuated or converted to fibers. The efficiency of fiber attenuation is facilitated as the stream S is influenced or biased by the pressure differential toward the plate **153** providing a snubbing point or inertia factor from which the fibers may be drawn or attenuated from the advancing tip of the stream by the forces of the blasts. Thus in this form of the apparatus the velocity of the blasts initiates the attenuation of fibers from the extremity of the stream and the divergently directed forces of the blasts at the crossover zone set up twisting or compound forces augmenting the attenuation or conversion of the material to fine fibers as it is carried along by the blasts.

The orifice construction illustrated in Figures 18 through 20 may be employed for the projection of other types of gases such as steam or air under comparatively high pressures to establish blasts of high velocities traveling in crossover relation to effectively convert flowable material to fibers.

Figures 21 and 22 are illustrative of another form of apparatus for carrying out the method of the invention. In this type of apparatus a single burner **170** is configurated to produce dual blasts of burned gases projected in crossover relation. The burner **170** is formed with a chamber **172** within which a mixture of fuel and air is burned which is supplied to the chamber through a manifold **173** from a mixture inlet pipe **174**. A wall **175** is disposed between the manifold and the combustion chamber which is provided with a plurality of small passages to admit the mixture into the chamber **172** and forms a fire screen to avoid ignition of the mixture in the manifold **173**.

The forward portion of the burner **170** is provided with a member formed with a pair of openings or orifices **177** and **178** preferably in the relationship illustrated in Figure 22. It should be noted that the orifices are of narrow elongated configuration so that the intensely hot exhaust or burned gases of combustion are discharged therethrough at relatively high velocities. As will be seen in Figure 22, the orifices are disposed in offset relation with respect to a vertical central plane through the burner and are arranged at a slight angle of convergence. The angularity of the side walls of the orifices is such as to direct the blasts toward each other so that they contact or brush each other at the crossover zone, the blasts traveling in substantially parallel planes as they leave the crossover zone. As shown in Figure 21, the blast-discharge orifices are arranged so as to direct the blasts B and B' in crossover relation and in divergent directions as they leave the crossover zone. The stream or body S of fiber-forming material may be delivered between the blasts into the crossover zone wherein the forces of the blasts attenuate, triturate or otherwise convert the material to fiber form. The fiber-forming material may also be delivered into the crossover zone as an elongated rigid or semi-rigid body, the advancing extremity of which is softened or reduced to flowable consistency to a degree that the material is readily acted upon by the blasts and converted to fibers.

Figures 23 through 25 inclusive illustrate a modified form of apparatus for carrying out the method of the invention utilizing a dual burner arrangement having a particular adjustable mounting or supporting means. Two burners **185** and **186** of substantially identical construction are supported upon a universally adjustable mounting structure adapted to facilitate varying or changing the angular or interrelated positions of the burners and hence predetermining the relation of the blasts to modify the operating conditions as desired.

The burners **185** and **186** in the illustrated embodiment and their mounting constructions are carried upon a shaft or member **188**. As the burners and the individual mounting means therefor are of identical construction, a description of one will suffice for both constructions. Each of the burners is provided with a skeleton supporting structure formed of a plate **190** provided with C-shaped members **192** which partially embrace and clamp the burner housings, as particularly shown in Figures 23 and 25, to provide supports for the burners. The plates **190** are bored and threaded to receive screws **194** which may be drawn up to securely retain the burner in the adjacent clamping members **192**.

Each of the plates **190** is secured to a tenon **196** formed upon a stub shaft **197**, the stub shaft passing through a bore formed in a boss portion **199** of an arm **200**. An opposite end portion of the arm **200** extends into a bore formed in a block or fitting **202**, the latter being formed with a transverse bore to be slidably received upon the supporting shaft **188**. Each block **202** is provided with a clamping screw **204** for securing the block to the member **200** and a second clamping screw **205** for securing the block **202** upon the shaft **188**.

The burners are individually adjustable about the axes of the shafts **197** and are adjustable about the axes of the arms **200** by rotation of the latter relative to the fittings **202**. The boss portion **199** of each member **200** has a threaded opening to receive a clamping screw **201** for securing the adjacent burner in fixed angular relation with respect to the arm **200**.

Each of the plates **190** is equipped with a graduated or calibrated scale **207** and each boss portion **199** is equipped with an index arm or indicator **208** for cooperation with the graduations on the scale **207**. The graduations represent degrees of the relative angular position of the burner about the axis of its supporting shaft **197**.

Mounted upon each member **200** is a collar **210** secured in adjusted position by a clamping screw **211**. One face of each block or fitting **202** is provided with a series of graduations **212** for indicating the inclination of the burners toward each other as they are adjusted about the axis

of the arm **200**. Each collar **210** is equipped with an index or indicator **214** adapted for cooperation with the graduations **212**. The burners may be moved toward and away from each other by releasing the clamping screws **205** and slidably adjusting the arms **200** and blocks **202** along the shaft **188**. The shaft **188** may be carried by a suitable supporting frame (not shown).

The mounting arrangement for the burners **185** and **186** provides for individual or independent angular adjustment of each burner about the axis of its respective supporting shaft **197**. To obtain a crossing of the blasts B and B', the burner **185** may be adjusted in one angular position as indicated in broken lines in Figure 24 and the burner **186** angularly adjusted in the opposite direction to direct the blasts in crossover relation. In order to cause the blasts at the zone of crossover to brush each other, the burners may be inclined through a slight angle whereby the blasts B and B' bear toward each other to establish contact of the adjacent gases of the blasts at the crossover zone. This adjustment of the burners may be attained by releasing the clamping screws **204** and rotating the arms **200** relative to the fittings **202**, the desired angularity from a vertical position being indicated by the position of the indicator **214** relative to the graduations **212**. When the proper regulation or adjustment of the relative positions of the burners is obtained, the clamping screws **201** and **204** may be drawn up to secure the burners in fixed positions.

The dual burner assembly as shown in Figure 23 is disposed beneath a feeder **216** from which a stream of glass S or other fiber-forming material is permitted to flow or be delivered into the crossover zone of the blasts. If desired, the fiber-forming material may be in the form of a rigid or semi-rigid rod which may be fed into the blasts of intensely hot burned gases of the blasts B and B', the heat of the blasts being sufficient to soften the extremity of the advancing rod and the forces of the blasts under high velocities acting in crossed or divergent relation serving to effectively convert or attenuate the softened material to fibers.

It is to be understood that the apparatus illustrated in Figures 23 through 25 is especially adaptable to form fibers by hot blasts emanating through restricted orifices associated with the burners. If desired, high velocity blasts of steam or air under pressure may be projected through the orifices in crossover relation to engage a stream of heat-softened or molten fiber-forming material to convert the same to fibers. Through the universal mounting arrangement for each individual burner, various angular positions of the burners may be had to vary or regulate the character and relative position of the crossover zone and the angularity of the attenuating forces of the blasts to establish different operating conditions for obtaining various types and sizes of fibers as desired for particular purposes.

Figures 26 and 27 illustrate a fiber-forming apparatus embodying the principles of the present invention and especially adapted to utilize blasts of steam, compressed air or the like in crossover relation for engagement with a plurality of streams of fiber-forming material. The apparatus is generally similar to that employed for attenuating heat-softened glass to form fibrous wool modified to carry out the method of the invention. The apparatus includes a feeder **220** forming a part of a forehearth **221** associated with a glass-melting furnace (not shown). The feeder **220** is provided with a plurality of spaced orifices arranged in one or more rows in the bottom of the feeder through which streams of molten glass are delivered from the forehearth. Disposed beneath and adjacent the feeder is a blower construction **224** which includes a member **225** formed with manifolds or chambers **226** communicating with horizontal passageways **228** adapted for discharging gases under pressure to provide high velocity attenuating blasts. The blower construction **224** illustrated is especially configurated for the utilization of steam as a fiber-attenuating force.

The member **225** is formed with a central passageway **230**, the opposing inner walls of the member **224** being slanted in a converging direction as shown in Figure 27. Guide or baffle plates **232** and **233** are attached to the inner opposed walls or faces **234** of the member **225** and are attached to said faces by means of screws **236** as shown in Figure 27. The member **225** is of elongated character as shown in Figure 26 and the slot or passageway **230** formed between the plates **232** and **233** extends substantially the full length of the block. A construction of this general character is illustrated in Slayter Patent 2,206,060.

The baffle plates are formed with narrow channels or grooves which are spaced at short intervals throughout the length of the plates and alternate with narrow ribs **221** between the grooves. The grooves **238** formed in baffle plate **232** are slanted downwardly and in a right-hand direction as viewed in Figure 26, while the grooves **239** in plate **233** are slanted downwardly and in a left-hand direction as viewed in Figure 26. When the plates **232** and **233** are secured to the member **225** in the position illustrated in Figure 27, the grooves are in registry with the passages **228** and extend downwardly below the passages, the grooves providing a multiplicity of small, downwardly extending, angularly disposed nozzles, passageways or orifices through which the steam or other gas under pressure is projected.

As the ribs bear against the inner faces of the member **225**, the grooves are thus separated so that a multiplicity of separate channels are provided so that gases are projected therethrough from the grooves in each plate to form a high velocity blast of relatively thin, sheet-like shape. The grooves **238** in the baffle plate **232** direct the gases in a right-hand direction as viewed in Figure 26, while the grooves **239** in the plate **233** direct the long thin blast of gases downwardly and in a left-hand direction.

It should be noted that while there is a slight convergence of the inner walls **234** of the passage **230**, the blasts travel downwardly in substantial parallelism yet have a brushing contact with each other. By reason of the non-intersecting paths of the blasts and the relative angular positions of the channels **238** and **239**, the blasts are caused to cross each other in a zone beneath the blower **224** which is herein referred to as the crossover zone.

The plurality of streams S of flowable fiber-forming material is directed from the feeder **220** into the crossover zone of the blasts. The high-pressure steam or air blasts move in divergent directions as they leave the crossover zone, and under the influence of the divergently acting forces and force couples set up by the high velocities of the gaseous blasts in crossing each other in brushing contact, the fiber-forming material delivered into the crossover zone is attenuated, triturated or otherwise converted into fiber form. The included angle between the nozzles or channels **238** and **239** may be from 20° to 35° for successful operation, and an included angle of 24° has, in actual operation, given very satisfactory fiber formation.

The fibers produced are of longer and finer character than those heretofore produced by the steam blast method such as the method disclosed in the Slayter and Thomas Patent No. 2,257,767. The fibers formed by the method of this invention are of an average length greater than those produced by the steam blast methods of conventional character shown in Patent 2,257,767, provide fibrous mats that are more resilient and by reason of the finer fibers, the mats are of low density. Another advantage attendant the attenuation of fibers through the use of the apparatus shown in Figures 26 and 27 lies in the fact that a larger proportion of the glass batch is converted to fibers with a corresponding decrease in the amount of unfiberized material in the end product,

Heretofore the unfiberized constituent of the fibrous mass was present in the form of spherically shaped pellets or shot. Through the utilization of the method of steam or air blasts in the apparatus of Figures 26 and 27, a much lower content of glass is present in shot or pellet form and a substantial portion of unfiberized material appears in the form of flakes or non-spherical configurations.

Figure 28 illustrates a modified form of the orifice plate arrangement shown in Figure 26 adapted for use in attenuating or converting flowable material to fibers through the use of steam or air blasts. In this form the individual blower units **225'** are provided with the orifice plates **248** and **249** which are inclined relative to each other and crossed in the manner illustrated in Figure 28. The serrations forming the orifices or openings in the plates **248** and **249** are disposed at right angles to the respective longitudinal axes of each orifice plate, and by disposing the plates in crossed or angular relation, the blasts are projected in crossover relation without especially configurating the gas passages in the plates in acute angular relation. In this form of apparatus, the streams S of fiber-forming material pass through the space or gap between the orifice plates **248** and **249** into the crossover zone of the blasts where the material is converted into fine fibers.

The arrangement illustrated in Figures 29 through 31 involves the formation of angularly converging blasts projected in crossover relation, this form of apparatus having particular utility in the formation of fibers from glass or other fiber-forming material wherein an intensely hot, high velocity blast is utilized to convert the material to fine fibers. The arrangement more especially involves an orifice construction wherein the crossover blasts are formed of gases of combustion from a single burner chamber which are discharged through orifices having blast-guiding surfaces arranged to cause the gaseous blasts to cross over and provide the divergently acting and compound forces for converting fiber-forming material to fibers or reducing material to a finely divided state. This form of apparatus embodies a blast-guiding orifice means for conveying the gases of the blasts to the crossover zone, the means being shaped to obtain the maximum velocity of the gases at the crossover zone and secure a high efficiency of material conversion or attenuation.

The burner chamber illustrated may be of the general character shown in Figure 21 and embodies a shell **260** having a refractory-walled interior forming a combustion chamber **262**, a combustible mixture of gases being admitted to a manifold **264**, the mixture passing through openings **265** in a wall **266** separating the combustion chamber from the manifold, the perforated wall **266** serving to avoid pre-ignition in the manifold.

The forward or nose end of the chamber is provided with an orifice plate or member **267** having orifices or gas discharge openings **270** and **271** respectively formed in angularly projecting bosses **274** and **275** formed on the plate. It should be noted, as particularly shown in Figure 31, that the guide walls **276** and **277** of the orifice **271** are inclined downwardly and the walls **278** and **279** are inclined upwardly causing the blasts of gas to pass each other at a crossover zone designated **280**. The plate or member **267** is formed with cooling chambers or passages **268'** having inlet and outlet pipes **268** and **269** for conveying water or other cooling fluid through the chambers **268'** to effectively cool the plate. It has been found that the point or zone of highest gas velocity of a blast is at its point of discharge from an orifice. In the apparatus shown in Figures 29 through 31, the guiding wall **276** directing the one blast in a downwardly direction and the wall **278** guiding the upwardly directed blast terminate at zone **285** at which zone the gases of the individual blasts are adjacent the crossover zone. Thus the highest velocities of the blasts exist as the gases leave the guide walls of the orifices and move into crossover relation. The stream of fiber-forming material S is delivered into the crossover zone of the blasts by feeding the material in a path adjacent the terminus of the orifice wall **276**. In this manner the fiber-forming material is fed into the zone of the greatest forces of the blasts, the gases of the blasts being at substantially their highest temperature and velocity providing for most efficient fiber attenuation or formation.

Figure 32 is illustrative of apparatus for converting material to fiber form or a finely divided state utilizing the constructional features and principles of operation of the arrangement shown in Figures 29 through 31. In this form two individual burners or combustion chambers are employed, each provided with a restricted orifice for the passage of gases to produce the blasts. In this arrangement burners **290** and **292** are arranged in downwardly converging relation and disposed at an included angle at which it is desired to cross the blasts. The lower or orifice end of each burner is provided with a projecting portion **294** within which is formed the restricted orifice or outlet through which the gases of combustion from the burners are discharged at high velocity. Thus the outer zone of each blast is prevented from expanding until the gases are close to the crossover zone so as to obtain the highest velocity of the blast at the zone into which the fiber-forming material is delivered. As illustrated in Figure 32, a stream S of glass or other fiber-forming material in a highly fluid state is directed into the crossover zone **296** so as to obtain a high efficiency of attenuation of material to fiber form or the conversion of material to a finely divided state or condition.

Figures 33 and 33*a* are illustrative of a modified form of orifice plate of the character shown in Figure 7 which may be employed to advantage with the arrangement of burners shown in Figure 1. The orifice construction is inclusive of a member **300** to which is assembled plates **302** and **303** spaced to form an elongated orifice through which gases of combustion from a burner (not shown) may be discharged at high velocities. As particularly shown, the forward edge **305** of the outermost plate **303** is angularly disposed and the wall portion **306** bounding one edge zone of the blast is of greater length than the wall portion **307** at the opposite edge zone.

By this construction the gases at the outer edges of the blasts are confined for a greater distance and hence their highest velocity is as close as possible to the crossover zone. Thus burners of the character shown at 14 in Figure 1 equipped with orifice constructions of the type shown in Figures 33 and 33*a* provide for maintaining high velocities for the gases as near as possible to the crossover zone. The plates or elements forming the passage for the gases are constructed to provide chambers of the character shown in Figure 8 through which a cooling fluid such as water or the like may be circulated, the water being conducted into and away from the cooling chambers by inlet and outlet pipes **309** and **310**.

Figures 34 and 35 illustrate semi-diagrammatically an arrangement of blast-forming means disposed so as to direct the blasts in substantially opposite directions or at a wide or obtuse angle of divergence and in crossover relation. The burners **315** and **316** are mounted in generally opposed relation, the angle of divergence being indicated at C in Figure 34. As shown the blasts are projected axially of the burners and in such arrangement the angle C represents the angle of divergence of the blasts B and B'. As represented in Figure 35, the blasts do not intersect but pass each other in brushing relation at the crossover zone. A stream or body S of fiber-forming material such as glass is delivered into the crossover zone and subjected to the forces of the high velocity blasts to disintegrate or attenuate the material into fibers with a minor amount of the material being reduced to fine flake-like particles. The burners are spaced laterally as shown in Figure 35 a sufficient distance to cause the blasts to cross in brushing relation and divergently ar-

ranged as in Figure 35 so that the blast from one burner does not impinge upon the opposite burner. If desired the forward portions of the burner constructions may be provided with cooling jackets (not shown) through which water or other cooling medium may be circulated.

The principle of operation of this apparatus is comparable to that of the other forms hereinbefore described with a high degree of turbulence or compound action of forces existing in the crossover zone due to the wide angle of divergence of the blasts resulting in high velocity couples of divergently directed forces which are effective to transform the material to fibers.

While in the several forms of apparatus disclosed the blasts are directed so as to cross each other in brushing relation, i. e., the adjacent boundary layers of gases of the blasts impinge each other to establish a swirling or turbulent condition in the crossover zone, the major volume of gases in each blast moves in rectilinear directions determined by the discharge angles of the orifices. An accurate analysis or explanation of the action of the compound forces in the crossover zone may not be completely determinable, but the novel results as exemplified by the high volume production of fine fibers with a greatly reduced proportion of unfiberized material in the end product clearly show that the method of crossing the high velocity blasts for fiber-forming purposes constitutes a novel improvement over prior processes of forming fibers.

Figures 36 and 37 illustrate an arrangement of carrying out the method of the invention wherein several blasts are projected in a manner to establish a plurality of crossover zones. As shown in Figure 36, burners **320** and **321** are arranged in adjacent relationship while burners **324** and **325**, arranged in adjacent relation, are disposed generally opposite the burners **320** and **321**. The burners may be supplied with combustible mixtures from manifolds **327** and **328**, the mixtures being burned within the chambers under confined conditions. The burned gases are discharged from the chambers through suitable restricted orifices arranged at the nose ends of the burners to provide high velocity blasts. As shown in Figure 37, the burners may be disposed in a downward direction and the orifice constructions thereof arranged to cause the blasts to cross one another.

The blast **332** from burner **320** crosses the blast **334** projected from the burner **324** to provide a crossover zone **335**. The blast **334** likewise crosses the blast **338** projected from the burner **321** to form crossover zone **337**. The fourth blast **340**, projected from the burner **325**, is in crossover relation with the blast **338** to form a third crossover zone **342**.

By this arrangement four blasts provide three independent crossover zones into which streams of fiber-forming material S may be delivered to establish a high yield of fiber production. Any number of blasts may be employed in the relationship similar to that illustrated in Figures 36 and 37 establishing a plurality of crossover zones, the number of which in any series will be one less than the number of blasts utilized for the purpose.

It is apparent that, within the scope of the invention, modifications and different arrangements may be made other than is herein disclosed, and the present disclosure is illustrative merely, the invention comprehending all variations thereof.

What we claim is:

1. A method of converting material to a finely divided form including establishing gaseous blasts moving in different directions and adapted to cross over each other in an X-like pattern with the adjacent edges of the blasts in brushing relation, and delivering material into the zone of crossover region of the blasts in a manner whereby the forces of the blasts act upon the material to reduce it to divided form.

2. A method of converting material to a finely divided form including establishing blasts of intensely hot gases moving in different angular directions and adapted to cross over each other in an X-like pattern with the adjacent edge zones of the blasts in brushing relation, and delivering material into the zone of crossover of the blasts in a manner whereby the heat and velocities of the blasts act upon the material to reduce it to divided form.

3. A method of disintegrating material to finely divided form including establishing a pair of blasts of gases moving at comparatively high velocities, directing the blasts in angularly related paths to cross over each other with the gases at the edge zones of the blasts in brushing relation to provide a turbulent zone, and delivering material into the turbulent zone whereby the forces of the blasts effect a disintegration of the material.

4. A method of processing heat-softenable material including establishing blasts of intensely hot gases moving in side-by-side relation in angularly related paths with the layers of gases at the adjacent boundary zones of the blasts in brushing relation, and delivering a body of heat-softenable material into the zone of brushing of the gases of the blasts whereby the forces of the blasts act upon the material to transform the same to fine fibers.

5. A method of converting heat-softenable material to fibers including establishing gaseous blasts moving in juxtaposed relation in angularly related directions crossing over one another with the adjacent layers of gases of the blasts in contacting relation, and delivering heat-softenable material into the crossover zone of adjacent blasts.

6. A method of producing fibers from fiber-forming material including burning combustible gases under confined conditions; discharging the burned gases through restricted orifices configurated and arranged to provide gaseous blasts of high velocity projected in angularly related paths in crossover relation with the adjacent boundaries of the gases of the blasts in contact to form a turbulence at the crossover zone; and delivering fiber-forming material into the influence of the blasts whereby the velocities of the blasts and the turbulence at the crossover zone convert the material to fibers.

7. A method of producing fibers from heat-softenable material including burning combustible mixture under confined conditions to provide gases of combustion of a temperature above the softening temperature of the material, discharging the gases of combustion through restricted orifices configurated and arranged to provide gaseous blasts of high velocity projected in angularly relation direction in crossover relation with adjacent areas of the gases of the blasts in brushing contact to establish turbulence at the crossover zone, and delivering heat-softenable material into the influence of the blasts whereby the heat and velocities of the blasts and the turbulence in the crossover zone convert the material to fibers.

8. A method of reducing material to a divided state including establishing gaseous blasts; discharging the gases forming the blasts from convergently disposed orifices to provide a V-shaped zone adjacent the orifices; directing the blasts in angularly related paths to cross over each other at the terminus of the V-shaped zone; and delivering a body of material through the V-shaped zone into the influence of the blasts at the crossing zone whereby the forces of the blasts disintegrate the material to a divided condition.

9. A method of processing heat-softenable material to fibers including establishing gaseous blasts moving at high velocities; discharging the gases forming the blasts from convergently disposed passages whereby the blasts move in paths providing a V-shaped zone; directing the blasts in angularly related paths to cross over each other at the terminus of the V-shaped zone with the boundary layers of the gases of the blasts in brushing relation; controlling the stream of induced air created by movement of the blasts to establish a reduced pressure in the V-shaped zone adjacent the discharge passages, and delivering a stream of heat-softened material through the V-shaped zone into the influence of the blasts at the

crossing zone whereby the forces of the blasts convert the material to fibers.

10. A method of processing heat-softenable material to fibers including establishing a plurality of blasts formed of streams of gas moving at high velocities; controlling the direction of flow of the gas streams forming the blasts whereby the blasts move in angularly related paths and are caused to cross over one another with the gas streams in brushing relation, and delivering a body of the material into the region of crossover of the blasts whereby the forces of the blasts attenuate the material to fibers.

11. Apparatus of the character disclosed, in combination, a pair of chambers adapted to burn combustible mixtures in confined zones, each of said chambers being formed with a restricted orifice through which the gases of combustion are discharged to provide high velocity blasts, the walls defining one of said orifices being angularly arranged with respect to the walls of the other and shaped to direct the gases to form blasts crossing each other in brushing relation, and means for flowing a stream of fiber-forming material into the influence of the forces of the blasts.

12. Apparatus of the character disclosed, in combination, a pair of chambers adapted to burn combustible mixtures in confined zones, each of said chambers being provided with a member formed with a restricted orifice through which the gases of combustion are discharged at high velocities, the walls defining one of said orifices being angularly arranged with respect to the walls of the other and shaped to direct the gases to form blasts crossing each other in brushing relation; means for delivering fiber-forming material into the crossover zone of the blasts, and means for cooling the member.

13. Apparatus of the character disclosed, in combination, a pair of chambers adapted to burn combustible mixtures in confined zones, each of said chambers being formed with a restricted orifice through which the gases of combustion are discharged at high velocities, the walls defining said orifices being shaped to direct the gases to form blasts crossing each other, and means for delivering fiber-forming material into the influence of the forces of the blasts.

14. Apparatus for processing fiber-forming materials including, in combination, means including a pair of chambers for burning combustible mixture in confined zones; means including a restricted orifice associated with each of said chambers through which the gases of combustion are discharged to provide high velocity blasts, the walls of said orifices being configurated and angularly arranged to direct the gaseous blasts from the respective orifices in crossover relation, and means for delivering fiber-forming material into the crossover zone of the blasts.

15. Apparatus for processing fiber-forming materials including, in combination, means for burning combustible mixture under confined conditions; means including a member having a pair of restricted orifices through which the gases of combustion are discharged to provide high velocity blasts, the walls defining said orifices being angularly arranged to direct the gaseous blasts from the respective orifices in crossover relation, means for delivering fiber-forming material into the crossover zone of the blasts, and means for controlling the temperature of the member.

16. Apparatus for processing fiber-forming materials including, in combination, means for burning combustible mixture under confined conditions; means including a pair of restricted orifices through which the burned gases are discharged as high velocity blasts, the walls of said orifices being configurated to direct the gases from the respective orifices in angularly directed paths in crossover relation, and means for delivering fiber-forming material into the crossover zone of the blasts.

17. Apparatus of the character disclosed, in combination, a pair of chambers adapted to burn combustible mixtures; means including restricted orifices associated with said chambers through which the gases of combustion are discharged to provide high velocity gaseous blasts; the walls of said orifices being arranged to direct the blasts in angularly related directions so as to cross each other in brushing relation; mounting means for said chambers; means for adjusting the mounting means to vary the relative positions of the chambers and the relative angularity of the walls of one orifice with respect to the walls of the other to change the directions of movement of the blasts, and means for delivering material into the influence of the blasts.

18. A method of processing heat-softenable fiber-forming material to fibers including establishing high velocity gaseous blasts directed in angularly related paths with the blasts in crossover relation and the adjacent edge zones of the blasts in brushing contact, and delivering fiber-forming material into the region of brushing contact of the blasts wherein the forces of the blasts convert the material to fibers.

19. A method of converting material to a finely divided state including establishing high velocity gaseous blasts, directing the blasts in angularly related paths with one blast crossing over another in an X-like pattern whereby the adjacent boundary gases of the blasts are in brushing relation, and delivering material into the crossover region of the blasts.

20. A method of processing fiber-forming material to fibers including establishing high velocity gaseous blasts, crossing one blast over another with the gases of adjacent edge zones of the crossing blasts in brushing relation, and delivering fiber-forming material into the region of crossover of the blasts whereby the forces of the blasts convert the material to fibers.

21. Apparatus for producing fibers including, in combination, means for establishing a pair of gaseous blasts traveling at high velocities, orifice means arranged to direct the blasts in angularly related directions whereby one blast crosses over the other with the boundary layers of gases of one blast brushing the boundary layers of gases of the other blast, and means for delivering fiber-forming material into the region of crossover of the blasts whereby the forces of the blasts convert the material to fibers.

22. Apparatus of the character disclosed, in combination, means for establishing gaseous blasts moving at high velocities, orifice means arranged to direct the blasts in angularly related paths in crossover relation whereby the adjacent boundary gases of the blasts are in brushing contact, and means for delivering material into the region of brushing contact of the gases of the blasts whereby the forces of the blasts act upon the material to change its form.

23. Apparatus of the character disclosed, in combination a chamber adapted to burn a combustible mixture under confined conditions, means associated with the chamber for discharging the gases of combustion at high velocities, said means including an orifice construction formed with converging passages through which the gases of combustion are discharged to provide high velocity blasts, the walls defining the passages being angularly arranged whereby the blasts are projected in crossover relation with the boundary layers of gases of the blasts in brushing contact, and means for delivering a body of fiber-forming material into the influence of the blasts.

24. Apparatus of the character disclosed, in combination, means for establishing streams of gas forming a pair of high velocity blasts, guiding means including a member formed with passages through which the streams of gas are projected, the walls defining the passages being arranged in converging relation whereby the blasts are projected in crossover relation with the boundary layers of gases of the blasts in brushing contact, and means for

delivering a body of material into the influence of the blasts.

References Cited in the file of this patent

UNITED STATES PATENTS

328,227	Kennedy et al.	Oct. 13, 1885
436,244	Kennedy	Sept. 9, 1890
2,175,224	Slayter	Oct. 10, 1939
2,206,060	Slayter	July 2, 1940
2,385,358	Hanson	Sept. 25, 1945
2,399,260	Taylor	Apr. 30, 1946
2,416,390	Hitt	Feb. 25, 1947
2,489,242	Slayter et al.	Nov. 22, 1949
2,563,080	Stalego	Aug. 7, 1951
2,571,025	Fletcher	Oct. 9, 1951
2,587,710	Downey	Mar. 4, 1952
2,614,619	Fuller	Oct. 21, 1952
2,626,424	Hawthorn	Jan. 27, 1953
2,643,415	Stalego	June 30, 1953
2,645,814	Stalego	July 21, 1953
2,717,416	Fletcher	Sept. 13, 1955

FOREIGN PATENTS

618,108	Great Britain	Feb. 16, 1949